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# EQUATIONS AND QUADRANT CHARTS FOR DETERMINING THE HEAT AND AIR REQUIREMENTS OF CONTINUOUS DRIERS*

By Hewitt Wilson† and Kenneth G. Skinner‡

Abstract

Equations were derived for determining the heat and air requirements of continuous driers or for given periods in a periodic drier. The four types of calculations are as follows: (1) heat balance for the drier from temperature, humidity, and weight data; (2) heat and air requirements when all data are known or assumed with the exception of the humidity or saturation of the exit vapor; (3) the saturation of the exit vapor under the conditions of (2); (4) temperature required of the hot entering air when all other data are known or assumed. Quadrant charts are given for the graphical solution of the equations. A psychrometric chart and a chart for converting metric to English units are also given.

## I. Introduction

The heat and air requirements of a drier depend upon (1) temperature and humidity of the outside air, (2) temperature and humidity of the entering air, (3) temperature and humidity of the exit gases, (4) temperature of the hot exit cars and dried product, (5) weight of water evaporated, (6) materials used for the drier cars and other furniture, and (7) radiation and other losses, which in this study are grouped as unaccounted-for losses.

The following four conditions of drier-heat balance and design are considered in this report:

(1) The method of calculating a heat balance for a continuous drier from temperature, humidity, and weight data is shown in equations (1) to (11) and in Figs. 1 to 5, inclusive.

(2) In designing a drier, the method of calculating the heat and air requirements when all data are known or assumed, with the exception of the humidity or saturation of the exit vapor, is shown in equations (5) to (8) and (12) to (15), inclusive, and Figs. 4 and 6.

(3) In designing a drier, the method of calculating the saturation of the exit vapor when all data are known or assumed, except the saturation of the exit vapor, is shown in equations (5) to (8), inclusive, (16) and (17), and Figs. 4 and 7.

(4) In designing a drier, the method of calculating the temperature of the hot entering air when all the data are known or assumed, except this temperature, is shown in equations (5), (6), (7), (8), and (18), and Figs. 1, 2, 3, 4, and 8. The basis used for the calculation is that the air required to carry the water-vapor equals the air required to supply the heat.

## II. Derivation of Equations

The equations were derived on the basis of 1000 kilograms of dried product. The calculation was simplified by using weights of dry air instead of volumes, which vary at different stages of the drying process. The vapor was considered as a fractional addition to the weight of dry air. The following symbols were used:

$A$ = summation of equations (5), (6), (7), and (8).
$B$ = barometric pressure (mm. mercury).
$c$ = weight of water evaporated per 1000 kg. dried product (kg.).
$g$ = weight of drier furniture per 1000 kg. dried product (kg.).
$H_g$ = specific heat of drier furniture.
$H_p$ = specific heat of dried product.
$L$ = unaccounted-for losses (percentage of total heat).
$m$ = weight of dry air (kg.).
$P_t$ = vapor pressure at $t$°C (mm. mercury).
$P_1$ = " " " $t_1$°C " "
$P_s$ = " " of saturated vapor at $t_1$°C (mm. mercury).
$P_{wb}$ = vapor pressure of saturated vapor at wet-bulb temperature (mm. mercury).
$t$ = temperature of outside air (°C).
$t_1$ = " " exit gases (°C).
$t_2$ = " " hot entering air (°C).
$t_3$ = " " exit cars and dried product (°C).
$t_{db}$ = dry-bulb temperature (°C).
$t_{wb}$ = wet-bulb " "
$w$ = weight of water-vapor per kg. dry outside air at $t$°C (kg.).

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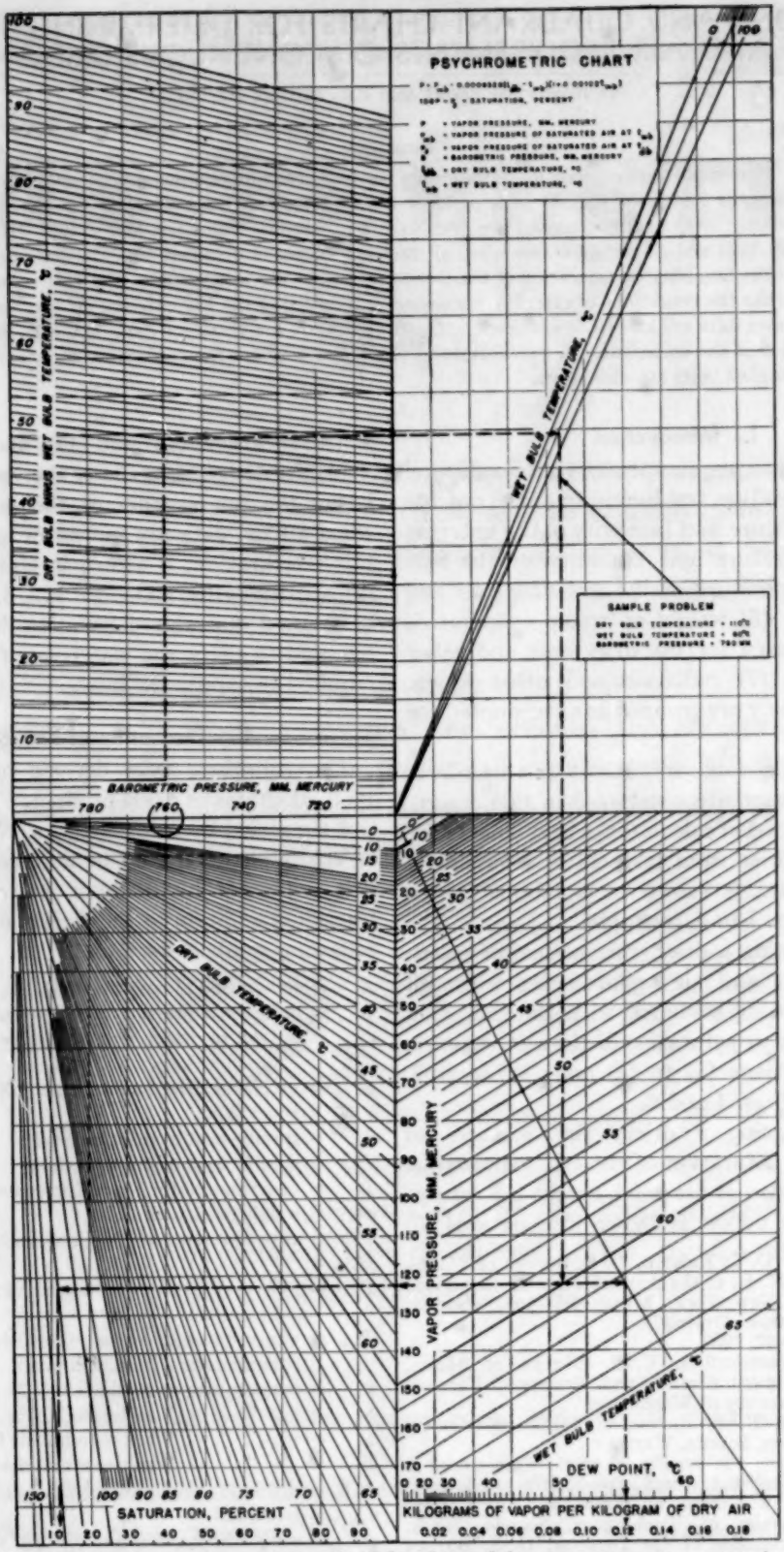


FIG. 1.—Psychrometric quadrant chart for determining vapor pressure, percentage saturation, dewpoint, and kilograms of vapor per kilogram of dry air.

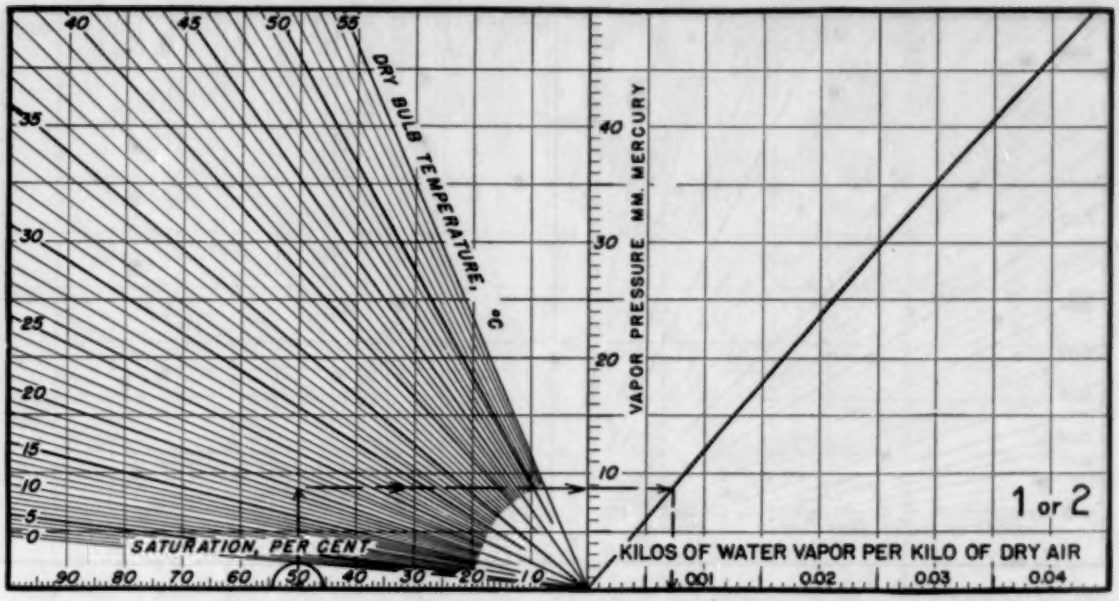


FIG. 2.—Quadrant chart for determining vapor pressure and weight of water-vapor per unit weight of dry air (equations (1) or (2)); the large numbers on the chart refer to equation numbers.

$w_1$ = weight of water-vapor per kg. dry exit gases at $t_1$ °C (kg.).

The specific heats of air and water-vapor vary with the temperature, but reasonable accuracy and simpler formulas can be obtained with the average values, 0.24 and 0.48, respectively.

### (1) Water-Vapor

The weights of vapor in the outside air and the exit gases per kilogram of dry air can be determined from the wet- and dry-bulb temperatures for low temperatures. For temperatures near the boiling point of water, it is necessary to use the direct-weight method with $P_2O_5$, calcium chloride, or similar absorbing agents.

The psychrometric chart (Fig. 1) was constructed from the equation[1]

$$P_t \text{ or } P_1 = P_{wb} - 0.000652B\,(t_{db} - t_{wb})\,(1 + 0.00102\,t_{wb}) \text{ (Fig. 1).}$$

$P_{wb}$ and other pressures of saturated vapor can be read from the lower vertical center line between the third and fourth quadrants of Fig. 1, using the diagonal-line temperatures either from the third or fourth quadrants.

$$\text{Weight of vapor/kg. dry outside entering air (kg.)} = \frac{0.6227\,P_t}{760 - P_t} = w \text{ (Fig. 2).} \quad (1)$$

$$\text{Weight of vapor/kg. dry exit gases (kg.)} = \frac{0.6227\,P_1}{760 - P_1} = w_1 \text{ (Fig. 2).} \quad (2)$$

[1] Donald B. Brooks, "Psychrometric Charts for High and Low Pressures," *Nat. Bur. Stand. Misc. Pub.*, No. 146, 4 pp. (1935).

The factor, 0.6227, is the ratio of the molecular weights of water and air or, considering both as perfect gases, the weight ratio per unit volume of vapor and air at all temperatures. Equations (1) and (2) are used instead of the product of the percentage humidity times the weight of water-vapor per cubic meter of saturated atmosphere, because the latter introduces large errors at the higher drier temperatures.

### (2) Dry Air Required for Vapor

The weight of dry air required to carry the water evaporated from the product is equal to the weight of water evaporated divided by the difference in vapor content of the outside air and the exit gases. This difference in vapor content is the weight of water removed by one kilogram of dry air.

$$\text{Weight of dry air required/1000 kg. dried product*} = \frac{c}{2 - 1} = \frac{c}{w_1 - w} \text{ (Fig. 3).} \quad (3)$$

$$\text{Weight of original vapor (kg.)*} = (1)\,(3) = \frac{cw}{w_1 - w} \text{ (Fig. 3).} \quad (4)$$

Figure 3 is the quadrant chart for equations (3) and (4).

*Case I: Calculation of Heat Balance on Vapor Basis When All Data Are Known or Assumed.*—Although different distributions of heat input may be used for a heat balance, that used in this

* Italicized numerals represent previous equations.

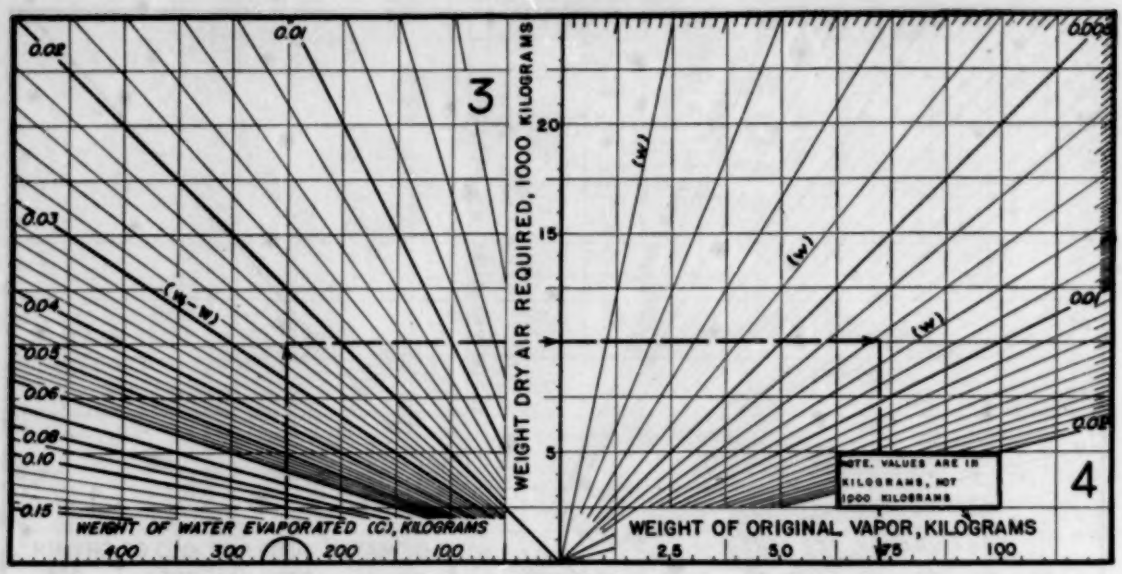


FIG. 3.—Quadrant chart for determining the weight of dry air required to dry 1000 kilograms of product and the weight of original vapor in the entering air (equations (3) and (4)).

study includes the useful heat required to warm the water in the product to the exit air temperature, $t_1$, and to evaporate it at that temperature. The remainder of the heat is lost by the hot drier cars, other furniture, and the hot dried product (when these three are removed at a temperature higher than the outside air), the stack losses, the heat of absorption,† and the unaccounted-for losses. Equations (5) to (11) detail these items.

Heat lost by hot cars and dried product (kilocalories) $= 1000(t_2 - t)H_p + (t_1 - t)gH_c$
$= (t_1 - t)(1000\ H_p + gH_c)$ (Fig. 4). (5)

Heat required to heat water (kilocalories) $= c(t_1 - t)$ (Fig. 4). (6)

Heat required to vaporize water (kilocalories) = $c$ (heat of vaporization at $t_1$) (Fig. 4). (7)

Heat required for heat of absorption (kilocalories) = 1000 (heat of absorption) (Fig. 4). (8)

The heat of vaporization at various temperatures is given in Fig. 4 on the horizontal line $x$–$x$. Equation (9) is not the total loss from the stack, since it does not include the loss from the vapor removed from the product. The total stack loss is $9 + 0.48c(t_1 - t)$. If the total stack loss were one of the items of the heat balance, a corresponding amount of heat must be subtracted from equations (6) and (7).

Heat loss from stack by dry air and original vapor (kilocalories) $= (t_1 - t)[0.24\,(3) + 0.48\,(4)]$ (9)
$= \dfrac{0.24\,c(t_1 - t)(1 + 2w)}{w_1 - w}$ (Fig. 5).

Total heat supplied by the hot entering air and vapor (kilocalories) $= (t_2 - t)[0.24\,(3) + 0.48\,(4)]$ (10)
$= \dfrac{0.24\,c(t_2 - t)(1 + 2w)}{w_1 - w}$ (Fig. 5).

Unaccounted-for heat (kilocalories) $= 10 - 9 - A$ (Fig. 5). (11)

$A$ is the sum of equations (5), (6), (7), and (8) (the basis for all the following calculations). Figure 4 shows the graph for equations (5), (6), (7), (8), and the summation, $A$, and Fig. 5 shows the graph for equations (9), (10), and (11).

The efficiency of a drier will depend upon the individual viewpoint as to the items that can be considered as useful heat, as well as the construction and operation of the drier for recovering heat from the hot ware, drier furniture, and stack gases. Some driers are better insulated than others, and one in Montana recovers a large portion of the heat of vaporization in a condensation system.

*Case II: Calculation of Heat and Air Required on Heat Basis When Humidity of Exit Gases Is Unknown.*—In Case I, the calculation was based

† Considered as zero for clay.

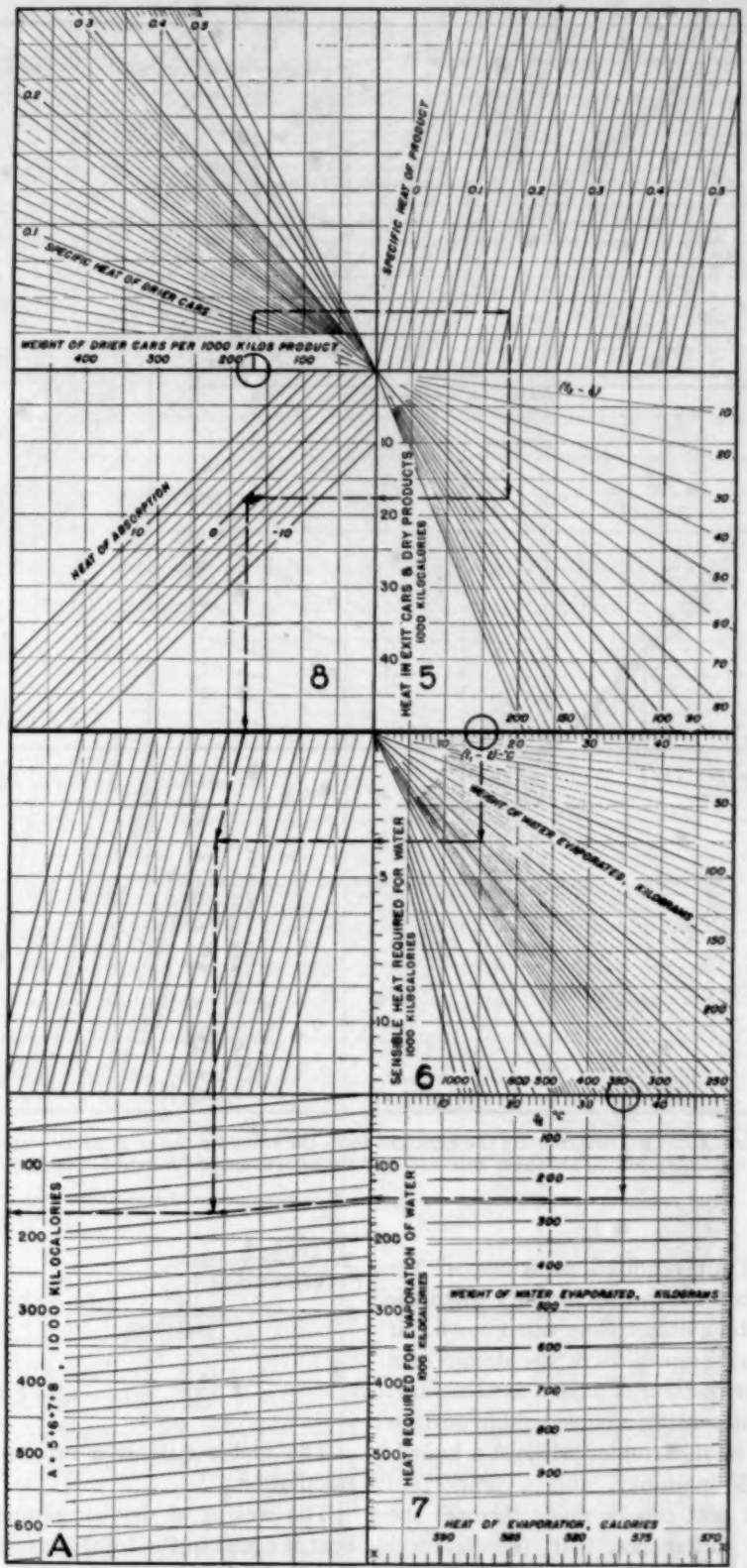
SPECIFIC HEAT OF DRIER CARS
SPECIFIC HEAT OF PRODUCT
WEIGHT OF DRIER CARS PER 1000 KILOS PRODUCT
HEAT OF ABSORPTION
8
HEAT IN EXIT CARS & DRY PRODUCTS 1000 KILOCALORIES
5
WEIGHT OF WATER EVAPORATED, KILOGRAMS
SENSIBLE HEAT REQUIRED FOR WATER 1000 KILOCALORIES
6
A = 5+6+7+8 1000 KILOCALORIES
HEAT REQUIRED FOR EVAPORATION OF WATER 1000 KILOCALORIES
WEIGHT OF WATER EVAPORATED, KILOGRAMS
7
HEAT OF EVAPORATION, CALORIES
A

FIG. 4.—Quadrant chart for determining the heat in exit cars and dried product, sensible heat required for evaporated water, heat required for evaporation, the heat of absorption, and the summation of these quantities (equations (5), (6), (7), and (8), and quantity $A$).

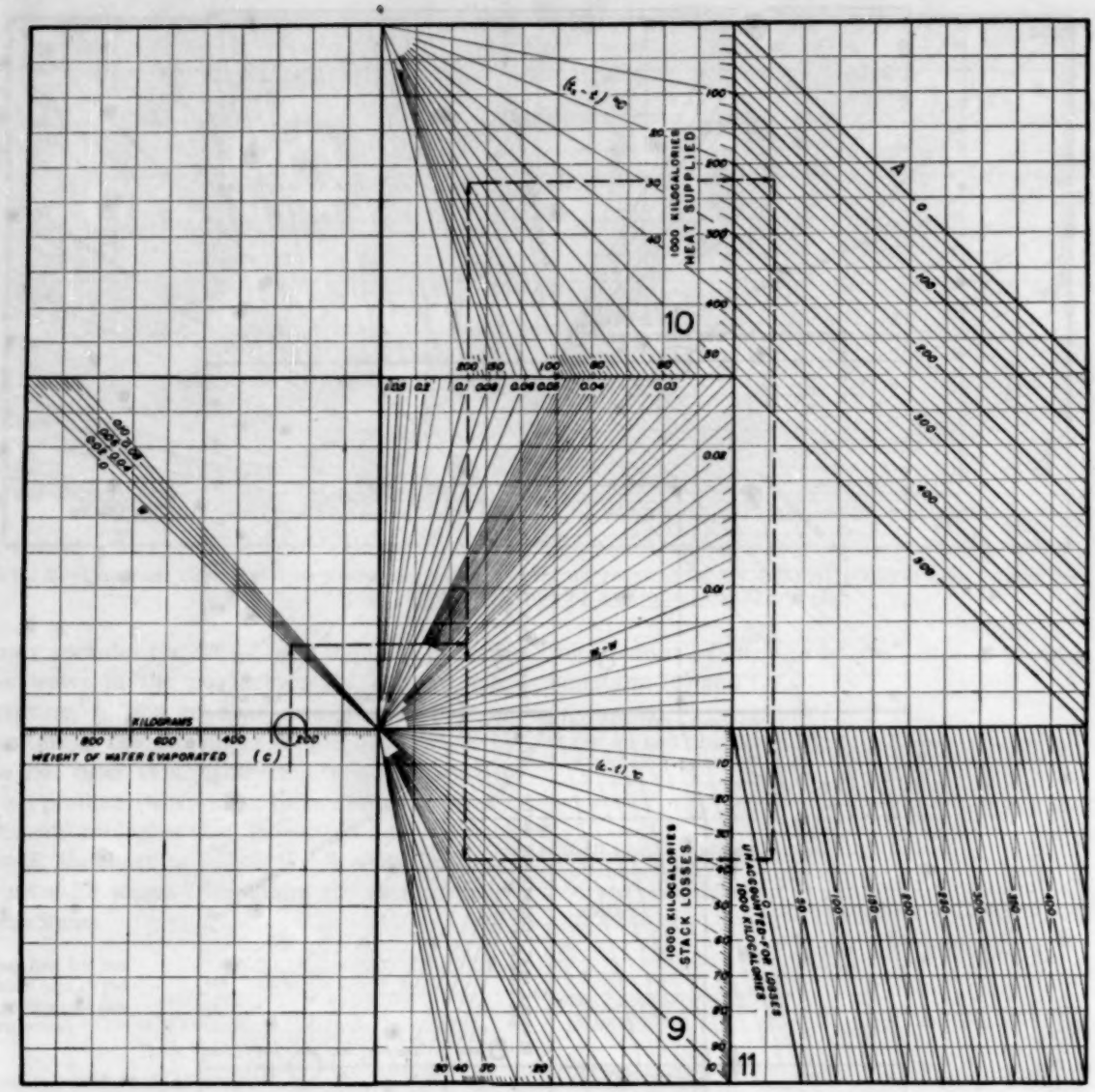


FIG. 5.—Quadrant chart for determining the heat lost from the stack by the original air-vapor mixture, the total heat supplied by the hot, entering air-vapor mixture, and the unaccounted-for heat (equations (9), (10), and (11)).

on the weight of air required to transport the water removed from the drying product when the humidity of the stack atmosphere was known. If the latter were not known, as in the design of a new drier, another method of attack is necessary. The value, $A$, representing a considerable portion of the heat, can be determined without a knowledge of the stack humidity, and a proportion of $A$ to the total heat can be made through the unit temperature differences, with $(t_2-t)$ representing the total heat, $(t_1-t)$, the stack losses, and $(t_2-t_1)$, the heat used in the drier.

$$\frac{\text{Total heat required (kilocalories)}}{\text{Total heat}} = \frac{A}{(t_2-t_1)-0.01\,L(t_2-t)} \quad (12)$$

$$\text{Total heat} = \frac{A\,(t_2-t)}{(t_2-t_1)-0.01\,L(t_2-t)} \quad \text{(Fig. 6)}.$$

The factor 0.01 is a reminder for percentage calculation.

The weight of dry air required to supply the heat is equal to the total heat divided by the heat supplied by one kilogram of dry air, with its accompanying original vapor.

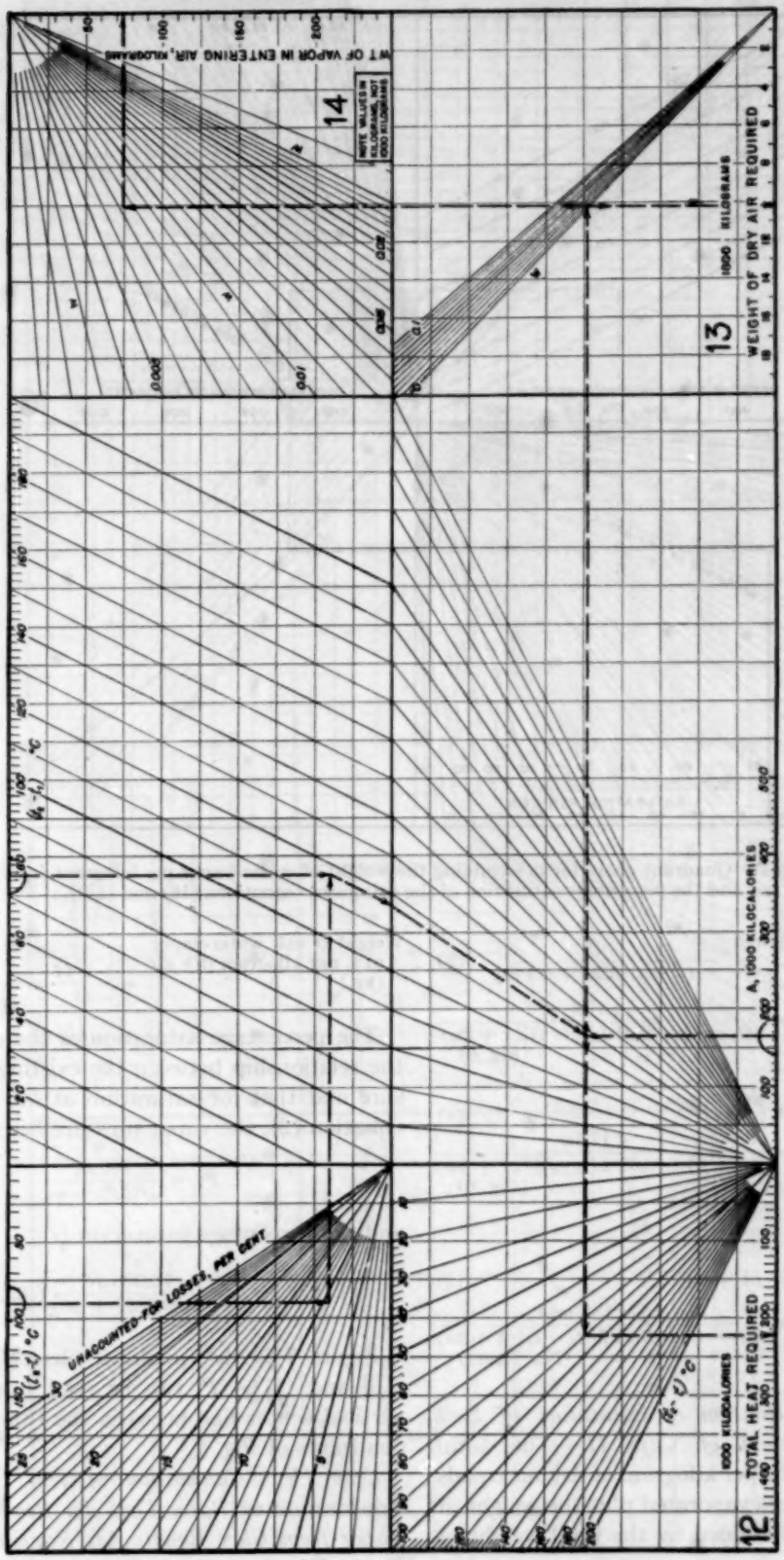


FIG. 6.—Quadrant chart for determining the total heat required, the weight of dry air required to supply the heat, and the weight of original vapor (equations (12), (13), and (14)). The percentage unaccounted-for losses are assumed.

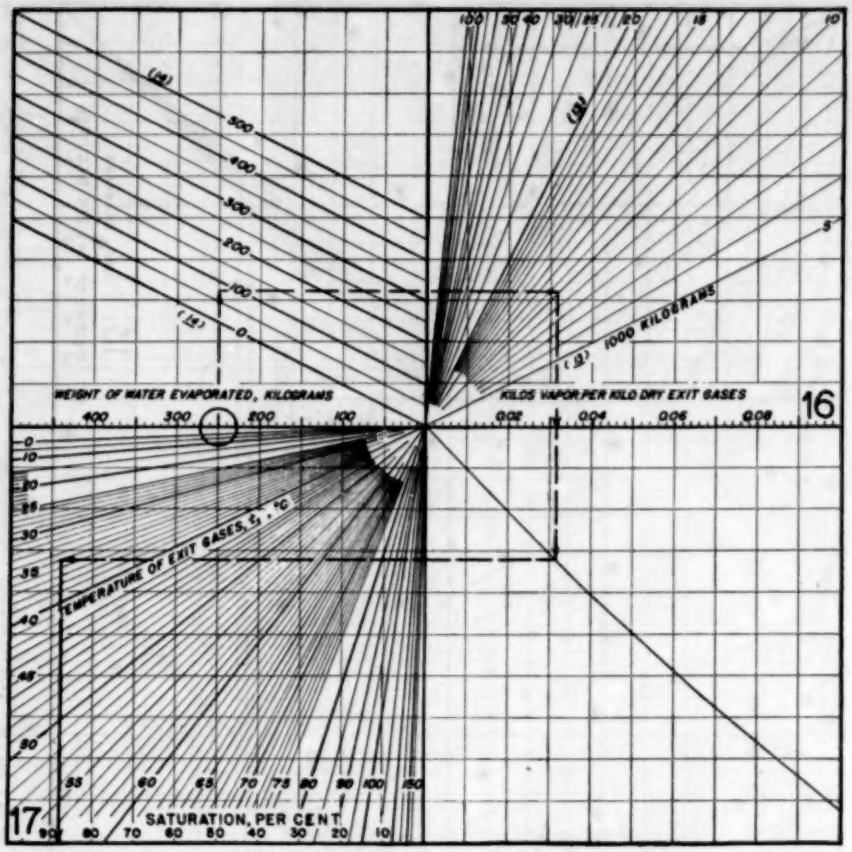


FIG. 7.—Quadrant chart for determining the weight of water-vapor per kilogram dry air and the percentage saturation of the exit gases (equations (16) and (17)).

$$\text{Weight of dry air required to supply heat (kg.)} = \frac{12}{(t_2 - t)(0.24 + 0.48w)} \quad (13)$$

$$= \frac{4.17A}{[(t_2 - t_1) - 0.01\,L(t_2 - t)](1 + 2w)} \text{ (Fig. 6)}$$

$$\text{Weight of original vapor (kg.)} = (1)\,(13) \quad (14)$$

$$= \frac{4.17Aw}{[(t_2 - t_1) - 0.01\,L(t_2 - t)](1 + 2w)} \text{ (Fig. 6)}$$

$$\text{Total weight of air and containing original vapor} = 13 + 14 \quad (15)$$

$$= \frac{4.17\,(1 + w)A}{[(t_2 - t_1) - 0.01\,L\,(t_2 - t)](1 + 2w)} \text{ (No figure)}$$

*Case III: Calculation of Saturation of Exit Vapor; Continuation of Case II.*—The total weight of exit vapor per kilogram of dry air equals the weight of water evaporated plus the weight of the original vapor divided by the total weight of dry air.

$$\text{Weight of exit water-vapor at } t_1 \text{ per kilogram dry air (kg.)} = \frac{c + 14}{13} = w_1 \text{ (Fig. 7).} \quad (16)$$

The percentage saturation of the exit vapor is the relationship between the existing vapor pressure and that for saturation at $t_1$. Transposing equation (2), the vapor pressure becomes

$$P_1 = \frac{760\,w_1}{0.6227 + w_1}$$

and the percentage saturation is

$$\text{Saturation of exit gases (\%)} = \frac{76{,}000\;16}{P_s(0.6227 + 16)} \text{ (Fig. 7).} \quad (17)$$

Figure 7 is the quadrant chart for equations (16) and (17). $P_s$ can be read from the lower vertical center line between the third and fourth quadrants of Fig. 1.

*Case IV: Calculation of Hot Entering Air Temperature on Basis That Air Required to Carry Vapor from Clay Equals Air Required to Supply Heat.*—The heat determination of equation (10)

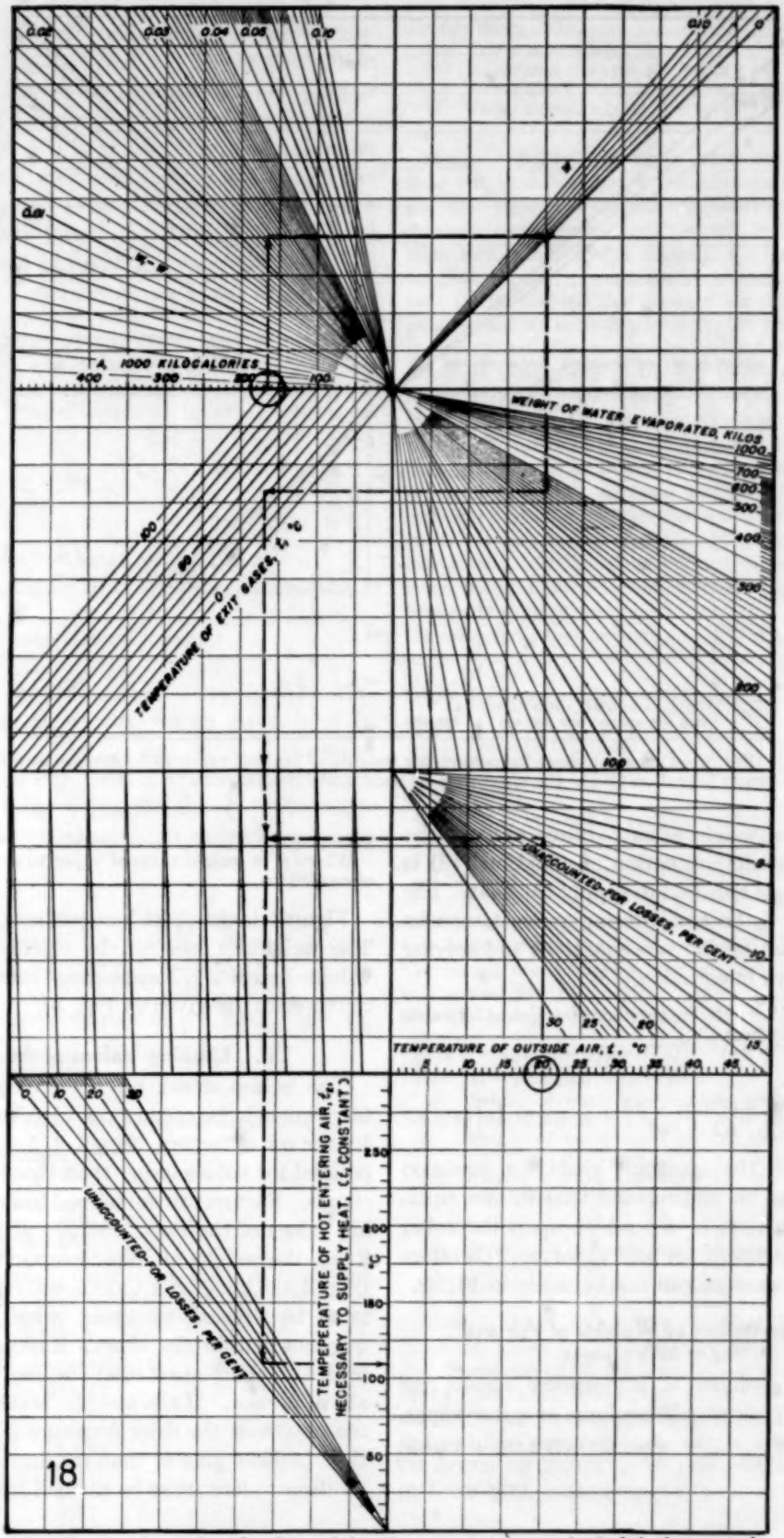


FIG. 8.—Quadrant chart for determining the temperature required of the hot, entering air which will supply enough heat for all the drying operations (equation (18)). *Basis:* Air required to carry water equals air required to supply heat.

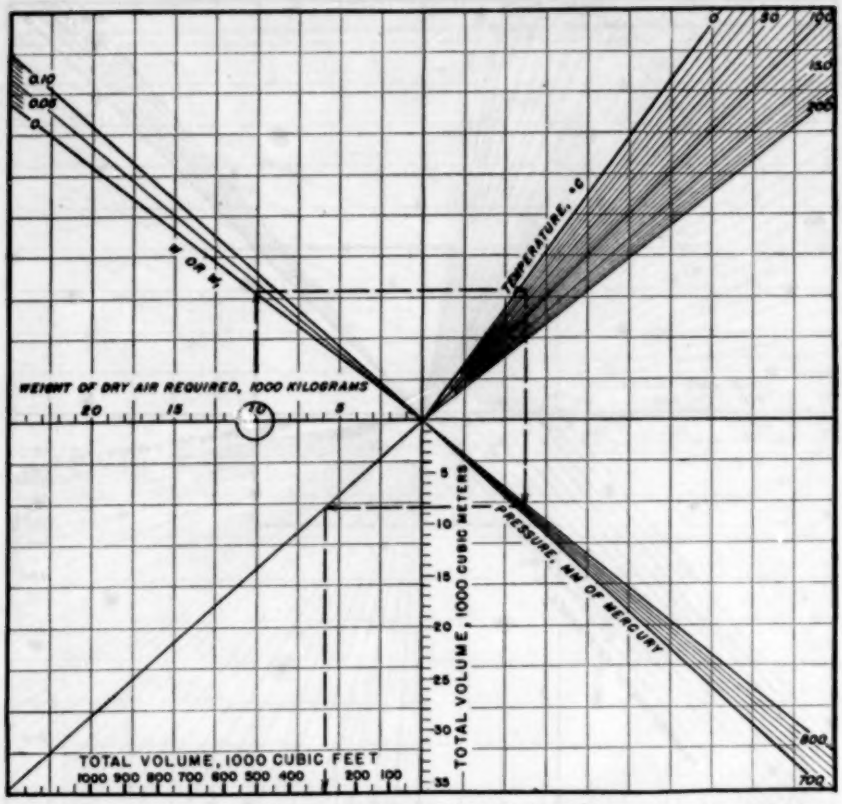
W OR $W_1$
TEMPERATURE, °C
WEIGHT OF DRY AIR REQUIRED, 1000 KILOGRAMS
PRESSURE, MM OF MERCURY
TOTAL VOLUME, 1000 CUBIC METERS
TOTAL VOLUME, 1000 CUBIC FEET

FIG. 9.—Quadrant chart for converting weights of air and vapor to volume measurements (equation (19)); the chart may be used in the reverse order.

is based on the weight of air required to carry the air. The heat determination of equation (12) is based on the air required to supply the heat. The temperature of the hot entering gases, $t_2$, can be found by equating the two equations and solving for $t_2$, as shown in equation (18).

Temperature of hot entering air when air required for vapor equals that for heat (°C) =

$$\frac{0.24\,c\,(t_2 - t)\,(1 + 2w)}{w_1 - w} = \frac{A(t_2 - t)}{(t_2 - t_1) - 0.01\,L\,(t_2 - t)} \qquad (18)$$

$$t_2 = \frac{1}{1 - 0.01\,L}\left[\frac{4.17\,A(w_1 - w)}{c(1 + 2w)} + t_1 - 0.01\,Lt\right] \text{(Fig. 8)}.$$

Figure 8 is the quadrant chart for equation (18). It must be remembered that in this equation the value, $A$, is dependent upon the other variables of temperature and vapor, and therefore independent changes can not be made in Fig. 8.

## III. Conversion of Weights of Air and Vapor to Volumes

The total volume of atmosphere equals the volume of dry air plus the volume of water-vapor.

Total volume of atmosphere (m.³), $V_{cm} = \dfrac{m(273 + t)(2.152 + 3.460w)}{B}$ (Fig. 9). (19)

Volume (ft.³) $V_{cf} = V_{cm} \times 35.31$. (20)

Where $w$ = weight ratio of vapor to dry air for any set of conditions.

Figure 9 is the chart for equations (19) and (20). The weight of gas can be calculated from the volume by using the same chart backward. Other conversions are given in Fig. 10.

## IV. Limiting Values of the Charts

The values shown on the charts may not be large enough for certain products and conditions. By the use of factors, Figs. 3, 4, 5, 6, 7, and 8 may be used for values larger than those shown on the charts. Factors can not be used to extend the limiting values of the Figs. 1, 2, 9, and 10. In Fig. 3, if ($c$), the weight of water evaporated, is greater than 1000 kilograms (100% water, dry basis), it must be divided by some value to produce a quotient within the chart's limits. The answer from the chart must then be multiplied by the above divisor. If the specific heats, $H_c$ or $H_p$, or the weight of the drier furniture (Fig. 4, in equation (5)) are greater than the limits of the charts, all three values must be divided by the same fac-

tor, and the answer multiplied by this factor. Factors can also be used for $(t_1-t)$ and $(c)$ in equation (6) and for $(c)$ in equation (7). To find the value of $A$ when a component of the equations (5), (6), (7), or (8) is greater than the values on the chart, the factor used for the solution of the equation must be used for the other equations and the answer found for $A$ be multiplied by the factor. If $A$ in Fig. 5 is greater than 500,000, then $(t_2-t_1)$, $(t_2-t)$, and $A$ must be divided by the

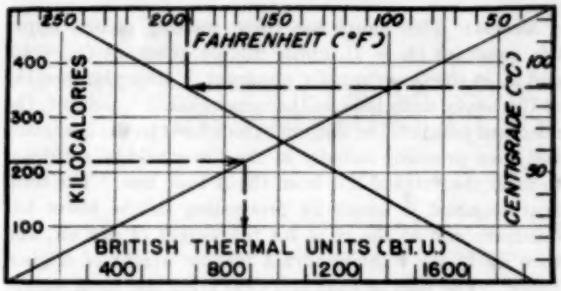


FIG. 10—Quadrant chart for converting metric heat and temperature units to English units.

same factor and the answer multiplied by this factor. Similar treatment can be given to $A$ in Fig. 6. But in Figs. 7 and 8, if $A$ and the weight of water are divided by the same factor, no correction is needed in the answer. The other charts must be reconstructed for greater values.

**Example**

*Given:*

(*a*) Outside air at 20°C, $t$, is 50% saturated.
(*b*) Exit vapor at 35°C, $t_1$, is 88.4% saturated.
(*c*) Temperature of the hot entering air, $t_2$, is 110°C.
(*d*) Cars and dried product leave at 100°C, $t_3$.
(*e*) Weight of cars, $g$ = 170 kg./1000 kg. dried product.
(*f*) Weight of water evaporated, $c$ = 250 kg./1000 kg. dried product.
(*g*) Specific heat of the cars, $H_c$ = 0.12.
(*h*) Specific heat of the product, $H_p$ = 0.20.

## V. Explanation of Charts and Examples[2]

**Figure 1.—Psychrometric Chart**

*Given:*

(*a*) Dry-bulb temperature, 110°C.
(*b*) Wet-bulb temperature, 60°C.
(*c*) Barometric pressure, 760 mm.

*To determine:*

(*a*) Vapor saturation (%).
(*b*) Kilograms of vapor per kg. dry air.
(*c*) Dew point (°C).
(*d*) Vapor pressure (mm. mercury).

*Method:* Follow the heavy dash line in upper left quadrant from base line at 760 mm. up to the diagonal line that represents the difference between the wet- and dry-bulb temperatures (110° − 60° = 50°); continue right horizontally to the diagonal line for the wet-bulb temperature (60°); vertically downward in third quadrant to the diagonal line representing the wet-bulb temperature again; horizontally to the left where the vertical scale indicates a vapor pressure of 122.5 mm. of mercury. Continue horizontally to the left to the diagonal line in fourth quadrant representing the dry-bulb temperature (110°) and vertically downward to the percentage saturation scale on base line (11.4%). A horizontal line drawn from the junction in the third quadrant to the right will intersect the single diagonal line, and a vertical line dropped from this intersection will give the weight of vapor per unit weight of dry air (0.12 kg.) and also the dew point (55.9°C). The saturated vapor pressure for a given temperature is shown on the central vertical line between the third and fourth quadrants. For example, the saturated vapor pressure for 61°C is 155 mm. of mercury.

**Figure 2.—Equations (1) and (2)**

*Given:*

(*a*) Temperature of outside air ($t$), 20°C.
(*b*) Percentage saturation, 50%.

*To determine:*

(*a*) Vapor pressure in mm. of mercury.
(*b*) Weight of water per unit weight of dry air.

*Method:* Starting at 50% saturation on the base line of the left quadrant, follow the heavy dash line vertically to 20°, and then to the right where the scale on the vertical axis indicates a vapor pressure of 8.7 mm. of mercury. Continuing horizontally to the diagonal line and down to the base line of the right quadrant gives 0.0072 kg. of water-vapor per kg. dry air.

**Figure 3.—Equations (3) and (4)**

*Given:*

(*a*) Weight of water evaporated per 1000 kg. of dry ware, 250 kg.
(*b*) Weight of water-vapor per kg. dry outside air at $t$°C ($w$), 0.0072 kg.
(*c*) Weight of water-vapor per kg. dry exit gases ($w_1$) at $t_1$°C, 0.03185 kg.

*To determine:*

(*a*) Weight of dry air required per 1000 kg. dried product.
(*b*) Weight of original vapor with entering air.

*Method:* From 250 kg. on the base line of the left quadrant, follow the dash line vertically to the diagonal line representing 0.0246 kg. vapor and then horizontally to the right to the vertical axis, which indicates 10,150 kg. dry air. The same line, continued horizontally to the diagonal line representing the weight of water-vapor in the outside air (0.0072 kg.) and dropped to the base line, indicates 73 kg. original vapor with the 10,150 kg. dry air.

[2] Full-size blueprints of the charts shown in this report may be obtained from the College of Mines, University of Washington, Seattle. Respective prices and sizes of the prints are as follows:

| Fig. No. | Approximate size (in.) | Price each (cents) |
|---|---|---|
| 1, 4, 6, 8 | 20 x 44 | 45 |
| 2, 3 | 12 x 22 | 15 |
| 5 | 33 x 34 | 50 |
| 7, 9 | 22 x 24 | 20 |
| 10 | 9 x 10 | 5 |

The full set will be furnished for $2.75.

The total weight of dry air and accompanying vapor is then 10,223 kg.

**Figure 4.—Equations (5), (6), and (7)**

*Given:*

(*a*) Weight of drier cars per 1000 kg. of product (*g*), 170 kg.
(*b*) Specific heat of drier cars ($H_c$), 0.12.
(*c*) Specific heat of product ($H_p$), 0.20.
(*d*) Temperature of exit cars and dried product ($t_4$), 100°C.
(*e*) Temperature of outside air ($t$), 20°C.
(*f*) Temperature of exit air and vapor ($t_1$), 35°C.
(*g*) Weight of water evaporated per 1000 kg. of dried products (*c*), 250 kg.

*To determine:*

(*a*) Heat in exit cars and dried product, equation (5), 17,650 kg.-cal.
(*b*) Sensible heat required for evaporated water, equation (6), 3750 kg.-cal.
(*c*) Heat required for evaporation, equation (7), 144,000 kg.-cal.
(*d*) Summation of equations (5), (6), and (7), 165,400 kg.-cal.

*Method:* The procedure for the first four quadrants is similar to that explained in Figs. 1, 2, and 3. Sensible heat and heat-for-evaporation data are introduced in quadrants 6 and 7 and added to that obtained in the first four quadrants. The heavy-dash example lines in quadrant 5 parallel the directional lines in quadrants 5 and 8. The base line, *x–x*, of quadrant 7 gives the heat of evaporation for the temperatures shown at the top of the quadrant.

**Figure 5.—Equations (9), (10), and (11), Case I**

*Given:*

(*a*) Weight of water evaporated per 1000 kg. of dried product, 250 kg.
(*b*) Weight of water-vapor per kg. dry outside air (*w*) from Fig. 2, 0.0072 kg.
(*c*) Weight of water-vapor per kg. of dry exit air ($w_1$) from Fig. 2, 0.03185 kg.
(*d*) Temperature of outside air ($t$), 20°C.
(*e*) " " exit gases ($t_1$), 35°C.
(*f*) " " hot entering air ($t_2$), 110°C.
(*g*) Summation of *A* from Fig. 4, 165,400 kg.-cal.

*To determine:*

(*a*) Heat loss from stack by original air-vapor mixture, equation (9).
(*b*) Total heat supplied by hot entering air-vapor mixture, equation (10).
(*c*) Unaccounted-for heat, equation (11).

*Method:* Follow the heavy dash line which divides in the middle quadrant to obtain the stack loss in the lower middle quadrant and the total heat supplied in the upper middle quadrant. The stack loss and summation *A* are subtracted from the total heat supplied to give the unaccounted-for losses in the lower right quadrant.

The summation of the heat balance for these given conditions is as follows:

| | (Kg.-cal.) | (%) |
|---|---|---|
| Heat lost by hot cars and dried product | 17,650 | 7.9 |
| Heat required to heat water | 3,750 | 1.7 |
| Heat required to vaporize water | 144,000 | 64.7 |
| Heat loss from stack by dry air and original vapor | 37,100 | 16.7 |
| Unaccounted-for heat | 20,000 | 9.0 |
| Total heat supplied by hot entering air | 222,500 | 100.0 |

**Figure 6.—Equations (12), (13), and (14), Case II**

*Given:*

(*a*) Temperature of outside air ($t$), 20°C.
(*b*) " " exit gases ($t_1$), 35°C.
(*c*) " " hot entering air ($t_2$), 110°C.
(*d*) Percentage unaccounted-for losses (assumed), 9.0%.
(*e*) Summation *A* from Fig. 4, 165,400 kg.-cal.
(*f*) Weight of water-vapor per kg. of dry outside air, 0.0072 kg.

*To determine:*

(*a*) Total heat required, equation (12).
(*b*) Weight of dry air required to supply heat, equation (13).
(*c*) Weight of original vapor, equation (14).

*Method:* This figure has three starting points, upper left quadrant ($t_2 - t$), upper middle quadrant ($t_2 - t_1$), and *A* in the lower middle quadrant. After the meeting of the heavy dash lines in the upper middle quadrant, the resultant parallels the diagonal guide lines to the boundary and then proceeds radially in the lower middle quadrant to meet the vertical line from the *A* base line. The total heat required is found by proceeding to the lower left quadrant and to the right for the weight of dry air, and then up to the right quadrant for the weight of original vapor. The sum of (13) and (14) gives the total weight of entering air-vapor mixture.

**Figure 7.—Equations (16) and (17), Case III**

*Given:*

(*a*) Weight of water evaporated per 1000 kg. of dry ware (*c*), 250 kg.
(*b*) Weight of dry air required to supply heat, equation (13), Fig. 6, 10,150 kg.
(*c*) Weight of original vapor, equation (14), Fig. 6, 73.2 kg.

*To determine:*

(*a*) Weight of exit water-vapor per kg. dry air.
(*b*) Percentage saturation of exit gases.

*Method:* A simple four-quadrant chart is used.

**Figure 8.—Equation (18), Case IV**

*Given:*

(*a*) Summation *A*, 165,400 kg.-cal.
(*b*) Weight of original vapor per kg. dry air (*w*), 0.0072 kg.
(*c*) Weight of exit vapor per kg. dry air ($w_1$), 0.03185 kg.
(*d*) Weight of water evaporated per 1000 kg. dry product (*c*), 250 kg.
(*e*) Temperature of outside air ($t$), 20°C.
(*f*) Temperature of exit gases ($t_1$), 35°C.
(*g*) Unaccounted-for losses, 9%.

*To determine:*

(*a*) Temperature of hot, entering air which will supply enough heat for all the drying operations.

*Method:* This is a simple quadrant system with two points of entry: Cumulative *A* in the first quadrant, upper left corner, and the temperature of the outside air ($t$) in the sixth quadrant.

Where cumulative *A* is involved, an independent adjustment of the other factors can not be made without a corresponding change in *A*. For example, if $t$ or $c$ is varied, *A* must be changed accordingly. The new *A* can be obtained from Fig. 4.

**Figure 9.—Equation (19)**

*Given:*

(*a*) Weight of dry air, equation (13), 10,150 kg.
(*b*) Weight of vapor per kg. dry air (*w*), 0.0072 kg.
(*c*) Temperature of air (*t*), 20°C.
(*d*) Barometric pressure (*B*), 780 mm. Hg.

*To determine:*

(*a*) Total volume in cubic meters and cubic feet.

*Method:* Simple quadrant chart for the above or other general values for transferring weights of air from the drier calculation to more common units for the design of flues, stacks, fans, and blowers.

Figure 10 shows the conversion between kilogram-calories and B.t.u., and Centigrade and Fahrenheit temperatures.

**Acknowledgments**

The writers wish to acknowledge their indebtedness to N. A. Carle, city engineer of Seattle, for his instruction in the quadrant-chart system, and to Bror L. Grondal, College of Forestry, University of Washington, and H. F. Yancey, U. S. Bureau of Mines, for their suggestions and corrections.

# A CRITICAL ANALYSIS OF SOME STATEMENTS AND EXPERIMENTS ON THE ADHERENCE OF SHEET-STEEL GROUND COATS*

By J. O. Lord

Abstract

A review and discussion are presented of the developments in the study of enamel adherence, notably in the publications of Kautz, Staley, and King.

## I. Introduction

In 1930 when King[1] organized a series of research programs entitled "Mechanics of Enamel Adherence," those of us who entered into the programs felt that the subject was not a simple one. A number of theories of adherence of widely different context with rather poor experimental support had been advanced by earlier workers. Some of these were accepted rather indifferently for lack of definite contradictory evidence, but it was apparent that much experimentation was needed to bring about a clear understanding of how and why glassy enamels adhere well or poorly to metal surfaces.

At that time the problem lacked definiteness. It was not entirely apparent what constituted good or bad adherence. Enamels would fail under one kind of test but stand up under others. Such conditions are frequently found in complicated problems and usually no single test is capable of qualifying the subject fully.

Thus far the results of these researches have been (1) the amassing of a large amount of data, some of it contradictory, (2) a few more theories, (3) a somewhat better knowledge of how to obtain desired results even where the reasons are not perfectly apparent, and (4) a somewhat clearer picture of the problem itself. Some of the questions to which answers must be obtained are known, and while the questions will require difficult and tedious experimentation, their solution will lead the way to a truly sound and extensive theory of adherence.

## II. Testing

As a rather rough method of arriving at some quantitative value that might be connected with adherence, the impact test[1] was generally adopted. This consists briefly of dropping a weight of 500 grams on a ball-pointed steel plunger which rests on the enamel surface. The height of the drop is increased by successive increments until the enamel cracks. It is easy to imagine objections to this test. For instance, the cracking strength of the enamel itself might have nothing to do with adherence yet it would affect the result. But this test seems to be the only physical test that can be relied upon for reasonably consistent results.

## III. The Dendrites

The development of a satisfactory method of preparing sections of enameled iron for micro-

* Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, March 31, 1936. Received April 17, 1936.

[1] (*a*) J. O. Lord and W. C. Rueckel, "Mechanics of Enamel Adherence: I," *Jour. Amer. Ceram. Soc.*, 14 [10] 777–81 (1931); (*b*) W. C. Rueckel and R. M. King, II, *ibid.*, pp. 782–88; (*c*) W. K. Carter and R. M. King, III, *ibid.*, pp. 788–94; (*d*) A. McK. Greaves-Walker and R. M. King, IV, *ibid.*, 15 [9] 476–80 (1932); (*e*) G. H. Spencer-Strong, J. O. Lord, and R. M. King, V, *ibid.*, pp. 480–83; (*f*) Karl Schwartzwalder and R. M. King, VI, *ibid.*, pp. 483–86; (*g*) G. H. Spencer-Strong, J. O. Lord, and R. M. King, VII, *ibid.*, pp. 486–90.

scopic study[1e] led to many interesting studies of the enamel-metal line of contact. Schwartzwalder[1f] melted some enamel in a fireclay crucible in which had been placed a piece of ingot iron, allowed it to cool slowly, and made a microsection through the iron. A bright metallic structure that looked like a string of triangular beads was found growing out in the enamel phase, the same kind of structure as the crystals of iron found occasionally in the shrinkage cavities of steel ingots. Metallurgists call these structures "dendrites," and this was unmistakably a dendrite. Nonmetals and compounds crystallize usually by the growth of faces, the result being a solid polyhedron of geometrical regularity. Metals, on the other hand, crystallize by growth along certain linear directions with branch growths appearing at nearly uniform intervals. This leads to a bush or tree-like structure, hence the name "dendrite." If a microsection is made through such a structure, the sections of a series of chopped-off branches appear as a series of uniformly spaced patches such as are shown in Fig. 1 of Schwartzwalder's paper.[2] The patches may or may not touch each other. They may not all be of the same size, although they will be nearly so, and the spacing will be reasonably uniform. Microscopic evidence seemed to identify the material of these dendrites as the same as the iron base, *viz.*, alpha (body centered) iron. It etched in acid at the same rate as the iron base, showed the same depth of scratches, and in some cases where the dendrites extended to the iron base and made contact with it there was no noticeable line of distinction. The X-ray diffraction pattern was that of alpha iron.

Following this discovery, old photomicrographs were resurrected and reëxamined for dendrite formations, and it was found in practically every case of a commercial ground coat against a commercial enameling iron that a string of metallic particles could be seen in the enamel phase a little distance from the iron base. These strings of particles had characteristics which led us to refer to them as dendrites. They had a reasonably uniform spacing and were fairly uniform in size. There is, however, one other characteristic of dendrites that was not taken sufficiently into account at that time, and the interpretation of these little particles of metal may have to be slightly modified if they do not fulfill that characteristic.

To understand this, the different modes of particle distribution should be considered.

## IV. Particle Distribution

(1) If a handful of sand is tossed on a smooth table and the arrangement the grains take is noted, there will be areas in which they are close together and areas where the grains are sparse, *i.e.*, there will be practically no uniform spacing with the grains separated by equal distances. This is sometimes called a "statistical distribution," and in any selected area the distances between grains will be determined by the law of probability.

(2) Precipitation from a supersaturated solution is considered, where the formation of a particle of precipitate depletes the solution so that no more material is available for precipitation in a certain small space. In such a case the particles will usually occur at regular intervals and of about the same size. This condition also obtains in the formation of a eutectic or eutectoid structure where a solution (solid or liquid) breaks down into two new crystal phases intimately mixed.

(3) Where dendrites form, the branches are all part of the same crystal and consequently will have, in addition to equal spacing and size, a positional relationship, *i.e.*, they will be arranged in strings or geometric figures of some kind.

Schwartzwalder's crystal is unmistakably a dendrite, but the lines of particles ordinarily found in the commercial ground coats apparently are not arranged in straight lines or geometric figures and consequently may have been formed by some other kind of precipitation. They are, however, of quite even spacing and (taking variations in level into account) of too uniform a size to be considered a statistical arrangement.

## V. Experimental Evidence

The discovery of these "dendrites" led to much speculation and the chemical reactions were studied to explain how enamels containing cobalt oxide could dissolve iron from the base and then precipitate it as dendritic crystals. The composition of the dendrites, from the microscopic and X-ray evidence, were known to be alpha iron, but Staley[3] suggested that we might be mistaken regarding the true nature of the dendrites. He stated that, from a theoretical basis

[3] See p. 485 of footnote reference 1 (*f*).

at least, the dendrites should be composed of cobalt, plated out of solution in the enamel by the superior electrolytic potential of the iron which was in process of dissolving. As a result of this discovery, renewed efforts were made to ascertain the true nature of the dendrites.

In the meantime, Staley made some experiments in support of his contention.[3] The "enamels" were water-soluble mixtures of borax glass and whatever metal oxide he wished to study. He found that he could cause any metal between iron and copper to plate out of the fused solution of its oxide by the introduction of a metal higher in the electromotive force series.

In July, 1934, Spencer-Strong and King published an article[4] in which the results of an extensive investigation of the phases present in various enamel systems were identified crystallographically and by X-ray. The conditions under which the various metals would plate out as dendrites were determined and the composition limits were recorded. It was found that when the cobalt oxide did not exceed 2½% only alpha iron appeared. With higher cobalt-oxide concentrations both alpha iron and cobalt formed. Similar results were found for nickel with nickel oxide. It is significant that iron, cobalt, and nickel were each identified by the X-ray, leaving no doubt as to the accuracy of their method.

This seemed to justify the belief that metallic alpha iron is the material that makes up the metal particles that are found near but are separated from the metal surface.

## VI. Theories of Adherence

The question, "what sticks the enamel on," has yet to be answered and Kautz[5] has presented a theory in which he takes into account all of the available data on the equilibrium between iron and its oxides. These data have been developed during the past twenty years by the Bureau of Standards, the Geophysical Laboratory, and a number of European and American investigators[6]. There seems to be enough reliable data on the subject to be of great value in analyzing the situation at the enamel-iron interface.

Kautz offers a clear and apparently undebatable argument to show that the electrolytic potential theory of Staley is inadequate to account for adherence. He also dismisses the idea of a gripping theory where dendrites or unevenness of the metal-enamel interface prevents the enamel from tearing away. He denies the original theory of dendrites of the writer and his coworkers, but he substitutes two kinds of iron particles, *viz.*, residual iron, left from the partly oxidized or dissolved crystals of iron from the metal base, and secondary iron, apparently formed by the decomposition of ferrous oxide. He states definitely that the cementing layer is a film of ferrous oxide about 0.00003 inch thick that lies between the enamel and the metal, and he shows many photomicrographs to support his contentions. Among a variety of techniques developed in his work is etching with an alcoholic solution of stannous chloride. This, according to Kautz, will dissolve the ferrous oxide most rapidly, $Fe_2O_3$ and $Fe_3O_4$ following, but it has no effect on iron or enamel.

## VII. Discussion of Kautz's Work

As mentioned previously, the term "dendrite" is perhaps not well chosen to describe the small particles of metal found embedded in the enamel. That some of them may be the result of the eutectoid decomposition of ferrous oxide at 570°C is freely admitted. A study of the iron-oxygen equilibrium diagram, however, indicates the possibility of gradual precipitation of $\frac{1.5}{22.5}$ or about 7% of the total weight of a ferrous-oxide phase (containing 22½% oxygen) if it is cooled from 1300°C down to 570°C. Furthermore, the diagram indicates that most of this precipitation will take place below 900°C. This gradual precipitation from a solid solution will give rise to a crystalline structure. The writer, however,

[3] H. F. Staley, "Electrolytic Reactions in Vitreous Enamels and Their Relation to the Adherence of Enamels to Steel," *Jour. Amer. Ceram. Soc.*, 17 [6] 163–67 (1934).

[4] G. H. Spencer-Strong and R. M. King, "Mechanics of Enamel Adherence: IX and X," *ibid.*, 17 [7] 208–19 (1934).

[5] Karl Kautz, "Further Data on Enamel Adherence," *ibid.*, 19 [4] 93–108 (1936).

[6] It is not the purpose of the writer to discuss the tremendous volume of work that has been done on iron-oxygen relationships. Those interested are referred to the following papers, in which will be found a complete exposition of all research done to date and a full bibliography.

(*a*) O. C. Ralston, "Iron-Oxide Reduction Equilibria," *Bur. Mines Bull.*, No. 296, 326 pp., 112 Figs. (1929).

(*b*) C. H. Mathewson, E. Spire, and W. E. Milligan, "Evolution of the Iron-Oxygen Constitutional Diagram," *Trans. Amer. Soc. Steel Treating*, 19 [11] 66–68 (1931).

(*c*) J. W. Greig, E. Posnjak, H. E. Merwin, and R. B. Sosman, "Equilibrium Relationships of $Fe_3O_4$, $Fe_2O_3$, and Oxygen," *Amer. Jour. Sci.*, [5] 30, 239–316 (1935); Geophysical Lab. Paper, No. 878; *Ceram. Abs.*, 15 [2] 74 (1936).

is not convinced that it may not be a liquid solution of ferrous oxide in enamel, in which case the formation of dendrites is the logical consequence.

The existence of residual unoxidized or undissolved grains of metal is another point on which the writer can not agree with Kautz. He indicates that slow oxidation of the metal base is the cause of an uneven line of contact and more of these detached grains, whereas rapid oxidation gives a smoother surface. In experiments on the "burning" of steel by Stead[7] and others early in this century, it was found that intergranular oxidation took place at very high temperatures where the grains were undergoing incipient fusion at their boundaries. At these temperatures the oxidation must have been very rapid. While this does not eliminate the possibility of intergranular attack at much lower temperatures, another consideration seems to eliminate the possibility of more than an occasional grain fragment, *i.e.*, the point mentioned earlier regarding distribution and size. A haphazard attack of a solvent or reagent against the metal surface must produce grain fragments, if at all, of widely varying sizes. They should vary from practically the full size of the grain in the metal to mere specks that are almost consumed. Furthermore, as we approach the metal there should be large fragments that are not quite loosened, peninsulas, so to speak. But in all the photomicrographs shown by Kautz and by other writers, the rough edges at worst have a sawtooth appearance.

It would be interesting to know how the sections shown in Kautz's paper were prepared. If they were taken normal to the plane of the interface, his contention for a layer of ferrous oxide 0.00003 inch thick at least will fit his own evidence. If, however, the material was sectioned on a bevel, as is usually done, the ferrous layer that he calls attention to may possibly be due to the appearance of the sloping metal through a thin wedge of enamel. It must be remembered that clean metal by any other than normally reflected light appears dark.

It is difficult to grasp the mechanism by which a layer of oxide that is only 0.00003 inch thick can form and be maintained at that thickness by solution on the other side in the enamel. It would seem that it ought either to increase rapidly in thickness or to be dissolved away almost immediately. It is easy to be misled by microscopic appearances, and this point should be checked by other methods before being accepted.

The statements regarding the behavior of the alcoholic stannous chloride etchant are not supported by any experimental evidence or bibliographic reference. This point should be made clearer.

It is not the writer's intention, however, to discredit Kautz's work in any way but rather to praise it as a valuable contribution based on fundamental knowledge. The approach to the problem through the study of the iron-oxygen equilibrium relations is a logical one and Kautz has presented it clearly. For ease of comprehension, we would like to dispense with the ferrous-oxide layer. It seems unnecessary and its absence would require only a slight modification of Kautz's theory. For instance, the enamel, dissolving the oxide clean from the metal, acquires high ferrous concentration at and near the interface. The contact between enamel and metal is perfect, and the enamel is of such a composition that reactions go on freely between enamel and metal, indicating chemical union. Any oxidation of the metal surface is immediately cleaned by the solvent enamel and the condition does not change. At lower temperatures, of course, some of these materials separate. Crystals form where the oxide concentration is high, but where the ferrous condition exists the breakdown from dissolved ferrous oxide to magnetite and alpha-iron particles takes place. The magnetite crystals are embedded in the enamel and do not materially affect adherence. This is also true of the particles of alpha iron.

Before any such theory can be accepted, however, more fundamental work must be done to determine solubility limits of the oxides in the enamel phase at various temperatures, a task which may be expected to give the research enthusiasts something to think about for some time to come.

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[7] (*a*) Alfred Stansfield, "The Burning and Overheating of Steel," *Jour. Iron Steel Inst.*, **2**, 433–62 (1903).
(*b*) F. Osmond and J. E. Stead, The Microscopic Analysis of Metals, Chapt. VIII, pp. 258–65. J. B. Lippincott Co., 1913 (also Charles Griffin and Co., Ltd., London, 1913).

# DISCUSSION ON LORD'S PAPER*

By Karl Kautz

Author's Note: There seem to be some points which are not clear and some omissions which have caused confusion in the paper[1] presented by the writer. Owing to the length of this paper, some data were purposely omitted for the sake of brevity. The writer wishes to thank Professor Lord for bringing these points to his attention and also for permitting this discussion of the preceding paper.

## I. Alcoholic Stannous Chloride

The use and behavior of alcoholic solutions of stannous chloride as an etchant for iron oxides has been reported by Campbell and Comstock,[2] by Wohrman,[3] and in the Metals Handbook.[4] We have used this solution in our laboratories for a number of years as an etchant in the study of ferrous-oxide inclusions in steel. That this solution does etch ferrous oxide is clearly shown in Fig. 7, which is the identical section of Fig. 6 after etching with alcoholic stannous chloride.[1] Pfeil[5] used a 0.1% HCl solution as an etchant for ferrous oxide, and the writer has also used this effectively for etching iron-enamel polished sections. Alcoholic stannous chloride, however, seems to give better results.

This solution is made by boiling an excess of mossy tin or block tin chips with concentrated hydrochloric acid until gas evolution ceases and then diluting the resulting solution with two to three times its volume of ethyl alcohol. Fresh solutions are much more effective as an etchant than old ones. This would indicate that the etching effect may be due to a small amount of free HCl still remaining in the fresh solution which later is neutralized by the excess tin.

## II. Cross-Sections of the Interface

All sections were cut and polished perpendicular to the plane of the iron-glass interface, and the photomicrographs were taken in normally reflected light. Sections cut oblique to the plane of the iron-glass interface have never been used because they are apt to be misleading.

## III. Thickness of Ferrous Oxide Layer

The specimen shown in Fig. 9 was obtained from a commercial plant and was considered to be a normal or commercial degree of adherence.[1] This specimen, however, was slightly overfired (shown by the thick, saturated dissolved layer of ferrous oxide) and was chosen because the ferrous-oxide film was thick enough to photograph well. The writer specifically stated that the film of ferrous oxide was "approximately $3 \times 10^{-5}$ inch thick in this specimen of normally fired ground-coat enamel." This figure was carried throughout the paper merely to give some numerical value or idea of magnitude to this ferrous-oxide film in enamels normally fired, but it has been interpreted by Lord to mean that the film always forms 0.00003 inch thick and is maintained constantly at this exact value for all degrees of firing. In fact, the converse is true. The film does not become visible at 1000 diameters until the molten glass becomes saturated with ferrous oxide at the interface thereby retarding the rate of solution. This usually occurs at that stage where the ground coat is considered to be fired properly. Continued firing produces ferrous oxide at the iron surface (by diffusion of oxygen through the molten glass) faster than it can be dissolved and diffused outward in the enamel so that the thickness of the film continuously increases. This is shown in Fig. 19 and Fig. 20.[1(a)] At the "burnt" stage the ferrous oxide may exist as large crystals in the glass and the total thickness of the layer may be from 10 to 50 times that at the normal stage.

## IV. Uneven Iron Surface by Oxidation

When sheet iron is heated in air at 1600°F, oxidation takes place rapidly, and the surface of the iron underlying the ferrous-magnetite scale is relatively smooth with no islands or peninsulas of iron visible. The same type of iron surface is seen immediately after fusion of ground-coat enamels on iron, so oxidation must also be rapid prior to fusion of the glass particles.

* Received May 20, 1936.

[1] Karl Kautz, "Further Data on Enamel Adherence," *Jour. Amer. Ceram. Soc.*, **19** [4] 93–108 (1936); p. 99.

[1(a)] *Ibid.*, pp. 105 and 106.

[2] W. Campbell and G. F. Comstock, "Method for the Identification of Nonmetallic Inclusions in Iron and Steel," *Proc. A.S.T.M.*, **1**, 523 (1923); *Met. Ind.*, **23**, 515 (1923).

[3] C. R. Wohrman, "Inclusions in Iron," *Trans. Amer. Soc. Steel Treating*, **14**, 81–126, 255–99, 385–414, 539–79 (1928); *Ceram. Abs.*, **8** [7] 488 (1929).

[4] Handbook, American Society for Metals, "Method for Identification of Inclusions," p. 636 (1933).

[5] L. B. Pfeil, "Constitution of Scale," *Jour. Iron Steel Inst.*, **123** [1] 237–38 (1931).

FIG. A.—Ground-coat enamel on iron immediately after fusion of the glass particles; unetched; × 1000.

In Fig. A, a ground-coat enamel is shown on deeply pickled iron after firing $1^3/_4$ minutes at 1600°F or immediately after fusion of the glass particles. The layer of initial ferrous-oxide scale is clearly seen completely covering the iron surface. The particles at the glass-scale interface must have been formed in the scale because they are imbedded in the scale; they are also present at the scale-iron interface and in the glass. Whether these are alpha-iron particles formed with the scale or crystals of magnetite has not been definitely established. It is not likely that they are secondary iron from decomposition of ferrous oxide, because they are imbedded in extremely viscous glass rigid at the temperature (1067°F) at which ferrous oxide decomposes. Their presence at the outer surface of the scale would indicate magnetite, for here the oxygen concentration could easily reach the stage where ferrous oxide alters to magnetite. Regardless of composition, however, these particles are not present after the initial scale has been dissolved, and aerial oxygen has penetrated the molten glass layer to the iron surface. The iron surface under this scale is fairly smooth and no islands or peninsulas of residual iron can be found. To illustrate further, the effects of slow and rapid oxidation at enameling temperatures upon the surface of the iron base (Figs. B, C, and D) are shown. Figure B shows enameling iron to which has been plated a thick layer of nickel by electrochemical deposition and which has been etched in 10% nital; note the average size of the ferrite grains at this magnification. Figure C shows the same iron and nickel plate after fusion of the ground-coat glass particles (fired $1^3/_4$ minutes at 1600°F). The oxidation was perhaps a little slower than under normal dried coats owing to the added thickness of the spongy nickel layer, but still rapid enough to produce the smooth surface characteristic of rapid oxidation. Figure D shows the same iron and plate of nickel after firing the ground coat six minutes at 1600°F. The initial scale was prevented from dissolving in the molten glass during the firing by the intervening layer of metallic nickel. In fact, the scale grew thicker with the additional firing by the slow diffusion of oxygen through the molten glass, the spongy nickel coating, and the layer of initial scale.

Oxidation took place here even more slowly than under normal thicknesses of ground-coat glass, and the typical uneven, sawtooth iron surface was obtained. It is significant that the molten glass never came in contact with the iron base, yet the same type of surface found under normally fired ground coats was obtained solely by slow oxidation. Even the isolated or detached surface iron particles were formed and imbedded in the scale.[5(a)] Because the scale was not molten at the temperatures used, the only conclusion that can be reached is that the particles of iron were undercut from the base and were formed simultaneously with the scale. On close examination, it will be seen that peninsulas and particles not entirely cut away from the base do exist, not by chemical reaction of glass with the iron but purely by oxidation.

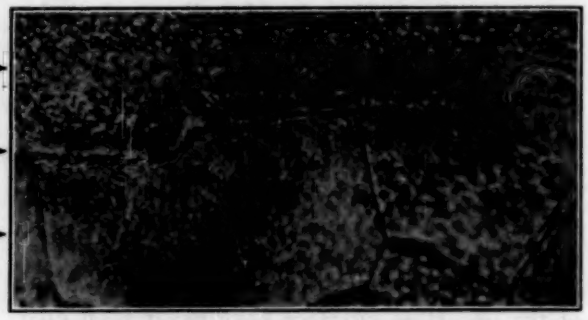


FIG. B.—Enameling iron with layer of chemically plated nickel attached; etched with 10% nital; × 1000. NOTE: The spongy chemical plate of nickel has largely been torn away in polishing. It can be seen as a heavy white line between the iron surface and the tin foil mounting.

## V. Intergranular Oxidation

It seems that Lord has confused this slow oxi-

[5(a)] This is not an assumption; examine Fig. D closely; also see footnote 1, p. 96 (Fig. 6).

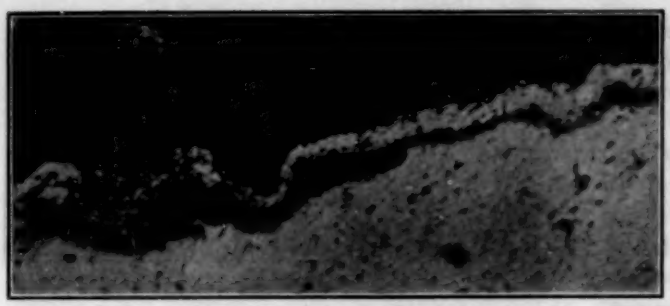

FIG. C.—Same as Fig. B immediately after fusion of ground-coat glass particles; unetched; × 1000.

dation with the excellent work of Stansfield[6] and Osmond and Stead[6] on "burnt steels." "Burnt steel" is simply steel that has been heated high enough to fuse the material composing the grain boundaries without melting the ferrite grains. This takes place even in an inert atmosphere, but in an oxidizing atmosphere some oxidation also takes place in the molten intergranular joints. By comparing the ferrite grain size of Fig. B with Fig. D, it will be seen that this slow oxidation is not intergranular, but that it takes place at irregular intervals across the exposed surface of the ferrite grain. The oxidation at grain boundaries certainly is not more pronounced than on the ferrite grains themselves. If this type of iron surface, produced by extremely slow oxidation at enameling temperatures, is unusual and has never been reported in the literature, then the facts shown above should be worthwhile data. The writer offers no explanation as to why iron should behave thus under extremely slow oxidizing conditions except that the ferrite grains themselves may not be perfectly homogeneous.

## VI. Metallic Particles Produced by Gases

The several investigators of metallic particles in and metallic layers under glasses fired on commercial iron seem to have overlooked the possibility of certain metals being reduced from glass solutions by the action of reducing gases evolved from the commercial iron base during heating.

Lucian and Kautz[7] made spectroscopic tests on the gases evolved when enameling iron and ground-coat enameled iron were heated. This investigation showed hydrogen and carbon monoxide accompanied by smaller quantities of their oxidation products, water-vapor and carbon dioxide, to be the principal components of these gases during the initial heating at low temperatures. Carbon monoxide was persistently evolved even after repeated heating and cooling *in vacuo* and at temperatures up to the melting point of the iron.

Freeman and Meloche,[8] by micro-gas analysis methods, gave the composition of the gases inclosed in the bubbles of clear glass fired on commercial iron. Their results show the total content of the reducing gases (hydrogen, carbon monoxide, and hydrocarbons) in the various samples analyzed to be 49.86, 27.86, 77.12, and 71.93%, respectively. The oxygen content and part of the nitrogen content probably were caused by the inward diffusion of air in the molten glass. It is probable, too, that the evolved gases were much more reducing in character than these results would indicate. Nevertheless, the gas mixture inclosed in these bubbles was sufficiently reducing at elevated temperatures to cause metallic reduction.

Staley[9] exhibited a steel pan in which a thick layer of a copper-borax glass had been fused.

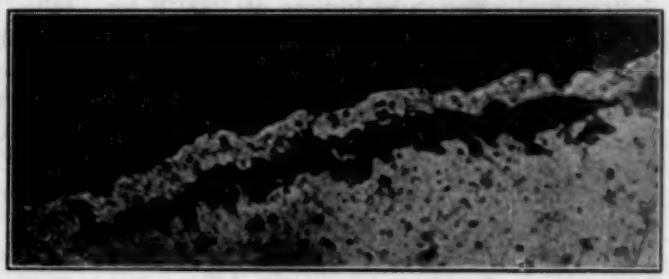

FIG. D.—Same as Fig. B after firing the ground-coat glass 6 minutes at 1600°F; unetched; × 1000.

Between the glass and the iron, a layer of metallic copper had formed. This layer of copper was believed to have been "plated out" of its solution in the glass by electrochemical action of the hot iron base. The writer noticed at the time that

[6] See footnotes 7 (*a*) and 7 (*b*), p. 114, this issue.

[7] A. N. Lucian and Karl Kautz, "Study of Gases in Enameling Iron," *Jour. Amer. Ceram. Soc.*, 17 [6] 167–72 (1934).

[8] S. E. Freeman and V. W. Meloche, "Micro-Gas Analysis of Gas Trapped in Vitreous Enamels on Enameling Iron during Firing," *ibid.*, 18 [4] 123–25 (1935).

[9] See footnote 3, p. 113, this issue.

on the contact side of the glass the copper was more brilliantly deposited on the interior of the bubbles or gas cavities than in direct contact with iron.

The writer has recently repeated Staley's interesting experiment a number of times. In some instances, the layer consisted of red cuprous oxide and in others metallic copper. The interiors of the gas cavities or bubbles at the interface were more brilliantly lined than were the portions in direct contact. The most interesting and unquestionable proof of the action of reducing gases was found in the bubbles in the interior of the glass layer. The glass broken so as to section these bubbles showed that the bubbles were perfectly and brilliantly lined with cuprous oxide (or copper). These bubbles were far removed from direct contact with the iron, so that their reduced lining or coating can be explained only by the action of gases.

It has been stated that the metals between iron and copper in the electrochemical series can be "plated out" of their glass solutions by the action of hot iron. It should also be remembered that these same metals are easily reducible metals, that is, their oxides or the glass solution of their oxides can be reduced by hydrogen or carbon monoxide at high temperatures. This is shown by the following simple experiments.

A porcelain boat was filled with commercial cobalt ground-coat enamel and heated in an electric combustion tube furnace at 1600°F for 30 minutes in a current of dry hydrogen and cooled rapidly (about $\frac{1}{2}$ hour) in the same atmosphere. Another porcelain boat filled with the same ground coat, which had been fired on iron to the normal stage and then carefully removed and finely ground, was heated alongside the first and given identical treatment.

With the pure ground-coat glass, numerous flakes or spangles of bright metal had formed on the surface of the glass. Some of these more

FIG. E.—Globules of nickel reduced from ground-coat enamel by hydrogen at 1600°F; unetched; × 500.

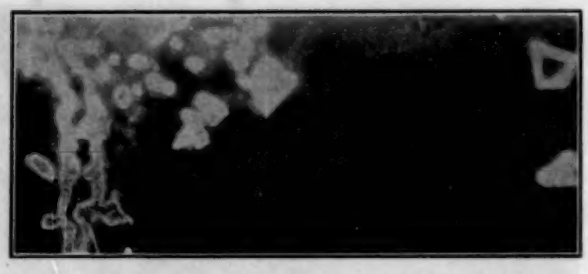

FIG. F.—Particles of iron reduced from ground-coat enamel rich in dissolved ferrous oxide by hydrogen at 1600°F; unetched; × 500.

than $\frac{1}{4}$ inch in diameter were carefully removed, and chemical analysis showed almost pure nickel with a trace of cobalt. A micro-section through the glass is shown in Fig. E. The glass, especially near the top surface, had numerous globules or spherical particles of metal, presumably nickel, imbedded in it. These globules ranged in size from those shown to some ten times this size. The balls or globules of nickel were characteristic and no other shape could be found.

The ground-coat glass, rich in ferrous oxide, had been severely reduced. A scum or crust of reduced metal more than one-half the depth of the original melt had formed over the glass. Analysis showed this metallic crust to be essentially iron with a small amount of nickel and a trace of cobalt. A micro-section through the narrow underlying glass is shown in Fig. F. Metallic globules, presumably nickel, were occasionally observed but are not shown in Fig. F. The small reduced iron particles have the appearance of oblate globules which later probably coalesce into large irregular shapes and stringers. Sometimes the iron exhibits almost perfect crystallographic outlines, in spite of the rapid cooling used.

If we adhere strictly to the meaning of dendritic, that is, "branching, tree-like, or fern-like," then none of these reduced metallic particles would be dendrites because they do not exhibit directional growth. Perhaps very slow cooling of the molten glass would promote this type of formation.

The gases evolved from hot commercial iron will cause similar reduction of the dissolved metallic oxides in ground-coat enamels. This is shown by the following simple experiment.

Freshly milled, pure commercial ground-coat slip was cast in the form of a disk on a clean

iron surface. After drying, this disk was approximately 3 inches in diameter and $^3/_8$ inch thick. A solution of sodium silicate (waterglass) was applied to this dried mass to prevent the easy escape of the evolved gases, and the sample was fired at 1600°F for six minutes.

The glass bloated approximately to double its original thickness and became quite vesicular from the escaping gases. Some bubbles were nearly $^1/_2$ inch in diameter and ranged down to microscopic size. The lower half of the large bubbles near the interface, that is, in the dissolved ferrous-oxide layer, were brilliantly lined on their interior with metal, undoubtedly iron. This experiment illustrates the ease with which dissolved ferrous oxide may be reduced from ground-coat enamels by gases evolved from commercial iron during heating.

## VII. Schwartzwalder's Dendrites

Schwartzwalder's dendrites, referred to by Lord, undoubtedly are true dendrites. They have the crystallographic appearance as well as the directional growth. These, however, were formed under unusual circumstances and not under the conditions existing in the commercial application of enamels. Schwartzwalder and King[10] definitely state that "enamel and ingot iron were placed in a fireclay crucible, heated to 1550°F for one hour, and allowed to cool for 24 hours."

One explanation for these naturally would be reduction by gases. Unless the furnace atmosphere was reducing or the iron was deeply immersed in the molten glass so that severe oxidation was prevented, it is not likely that the dendrites resulted from gas reduction.

The most probable explanation would be secondary iron. With the slow cooling employed, ferrous oxide probably decomposed more completely into magnetite and secondary iron so that the iron particles became much larger and dendritic. If they are secondary iron, they should be imbedded in scale and not in glass. The photomicrograph was not exposed long enough to bring out this distinction.

## VIII. Solution Bonds

In the industrial fields, there are numerous examples of adherence produced by solution bonds. A few examples are (1) mercury adhering to copper or gold by solution at the surface, (2) a galvanized zinc coating adhering to iron by solution at the surface, and (3) a glaze adhering to a fired clay body by solution of the clay body, and (4) glass adhering to refractory blocks by solution of the block surface. Why, then, could there not be a solution bond for vitreous enamels on iron? Here the conditions are ideal. Ferrous oxide is a substance which is soluble both in molten glasses and in metallic iron. Its solubility in ground-coat glasses has never been determined but probably is quite high (more than 30%). According to Castro and Portevin,[11] the solubility of FeO in alpha iron in terms of oxygen is about 0.075% at 870°C (1598°F). Translated into its equivalent of FeO, this would be 0.33% FeO in alpha iron. Krings and Kempkens[12] found the solubility at 715°C in pure iron (reduced $Fe_2O_3$) to be 0.11% oxygen or approximately 0.5% FeO.

It should make little difference whether the film of ferrous oxide under the molten glass be 0.00003 inch thick or submicroscopic (theoretically one molecule thick); the attractive forces of solution are still operative. The ground-coat glass and the alpha iron at high temperatures become the solvents competing for the solute, ferrous oxide. This competition, however, seems to be one-sided and the enamel bonds must necessarily remain fixed unless a way is found to increase greatly the solubility of FeO in alpha iron, which at present seems impossible.

## IX. Proposed Modification

The writer can not understand why Lord feels it necessary to dispense with the ferrous-oxide layer and to substitute clean contact between glass and metal. The writer has never found any evidence to support the hypothesis of chemical action between metallic iron and ground-coat enamel. In inert atmospheres or *in vacuo*, molten ground-coat glass can remain in contact with iron for long periods without any apparent attack on the iron surface[13] and without producing the adherence so familiar in ground coats fired on iron in air. Even under extremely thick layers of ground coats on iron (fired the usual

[10] See footnote 1 (*f*), p. 111, this issue.

[11] R. Castro and A. Portevin, "Actual State of the Methods for Determining the Oxygen and the Oxides in Iron and Steel," *Rev. mét.*, **29** [8] 418 (1932); see also Fig. 2 in footnote reference 1, p. 115, this issue.

[12] W. Krings and J. Kempkens, "Solubility of Oxygen in Solid Iron," *Z. anorg. allgem. Chem.*, **183** [10] 225, 250 (1929).

[13] See Fig. 16 (p. 104), footnote reference 1, p. 115, this issue.

time in air), the conditions postulated by Lord apparently do not exist. Oxygen diffusion through the molten glass has not yet reached the iron although the glass at the interface has acquired a high ferrous concentration from solution of the initial scale. While the initial scale is dissolving in the glass, it is also dissolving in the iron surface, and the surface, typical of slow oxidation, is produced but not at all as severe as under normal coats normally fired. Clean contacts apparently do not exist where this type of surface is present. Reducing conditions, however, favorable to metallic reduction by gases evolved from hot iron exist here.

The solution-bond explanation of adherence is not based on theory alone but on three facts, *viz.*, (1) that a film of ferrous oxide exists between the molten glass and iron at the normal stage (where good adherence is obtained), (2) that ferrous oxide is soluble in molten ground-coat glass, and (3) that ferrous oxide is soluble in alpha iron.

## X. Data Needed

The writer agrees with Lord that much data on the behavior of ferrous oxide in enamels must be obtained. Some of the outstanding problems are as follows: (1) the solubility of ferrous oxide in enamels of varying compositions at different temperatures; (2) the effect of various concentrations of ferrous oxide in solution in enamels upon the coefficient of expansion, elasticity, fusibility, and other physical properties; (3) the rate of diffusion of ferrous oxide in molten enamels of different compositions; and (4) the laws governing the diffusion or permeability of gases (especially oxygen) through molten glass layers of different compositions alone and with varying concentrations of ferrous oxide at different temperatures.

Studies involving ferrous oxide must necessarily be conducted in an inert atmosphere, such as helium. Reducing atmospheres tend to reduce the glass solutions of ferrous oxide to metallic iron and oxidizing atmospheres to oxidize them to magnetite. Even nitrogen is not wholly inert in its action upon iron.

Republic Steel Corporation
Massillon, Ohio

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# REPLY TO KAUTZ DISCUSSION*

By J. O. Lord

The discussion presented by Kautz has included many new ideas and suggestions. His answer to the question (see pp. 114 and 115) regarding the alcoholic solution of stannous chloride as an etching reagent for oxides of iron indicates that he has satisfactory evidence as to its effectiveness.

Since he permits the "ferrous oxide" layer to reduce to "even one molecule thick," the possibility of making it even less than one molecule thick may eventually bring our ideas on this point together.

As to his work on the unevenness of the ferrite surface, our observations on this point are somewhat contradictory, and I believe that evidence should be accumulated from a number of different investigators to determine the consistency of this behavior.

We seem to have no difference in the concept of what constitutes dendrites. The conditions under which they form, however, are still questioned.

As a proponent of microscopic technique, I feel forced to discuss its limitations. The fact that its findings are visual and largely qualitative limit its usefulness as an analytical tool. It offers suggestions and furnishes illustrations of facts determined by other methods. Its findings can not be accepted as proof, however, unless supported by chemical and X-ray evidence. It is from this viewpoint that Kautz's work may be considered as opening the way to more extended experimentation.

The idea of precipitation of metal from the enamel phase by the action of reducing gases is interesting. Such an idea deserves extended study and research. Suggested relations between CO gas, iron, and oxides of iron in the enamel will be found in a concurrent paper by

* Received June 26, 1936.

Connelly and Lord[1] on reboiling. That CO gas is present was recently demonstrated by Lucian and Kautz,[2] who used spectroscopic methods to determine this fact.

[1] D. S. Connelly and J. O. Lord, "Microscopic Studies of Reboiling Phenomena," *Jour. Amer. Ceram. Soc.*, 20 [1] 10–16 (1937).
[2] See footnote 7, p. 117.

This and several other new observations, included in the Kautz discussion, are a little beyond the scope of my original paper. For this reason I shall defer comment upon them until Kautz presents them in the form of original articles.

## DISCUSSION OF LORD PAPER*

By Homer F. Staley

### I. Introduction

Lord states that "Kautz[1] offers a clear and apparently undebatable argument to show that the electrolytic potential theory of Staley[2] is inadequate to account for adherence. He also effectively dismisses the idea of a gripping theory where dendrites or unevenness of the metal interface prevents the enamel from tearing away."

That any theory proposed by me should not meet immediate acceptance, or ever, is not of importance. Even that the hitherto generally accepted gripping theory of adherence is questioned by an individual experimenter is not of great moment. But my paper[2] offers a point of view and suggests methods of approach to problems in enameling technology that seem worthy of further study. Moreover, the idea of promoting better gripping of the base metal by the ground coat is a fundamental part of modern enamel technique. Therefore, in the interest of the development of enameling technology, it seems worth while to keep these two questions open.

### II. Kautz' Experiments in Electrolytic Precipitation

Kautz tried to enamel, with a commercial ground coat containing cobalt, various metals ranging from chromium, high in the electromotive series of metals, to gold which was very low in the electromotive series of metals. He concluded that the positions of these metals in the electromotive series have no direct relation to the adherence of a commercial ground coat containing cobalt to these metals. This was to be expected. Many factors, such as the structure of the metal surface, presence of oxide on the surface, coefficient of thermal expansion of the metal, and ease of wetting of the surface by the enamel, etc., affect the adherence of a ground coat so greatly that no one could reasonably expect the relative ease with which cobalt should be precipitated out of the ground coat to be the controlling factor in adherence. In the writer's paper,[2] he has shown that the relative ease with which various metals should be precipitated from an enamel onto a steel base bears no relation to the adherence of the ground coat. Of the eight metallic oxides tried, copper should be precipitated the most readily and cobalt the least readily. But copper gave only fair adherence and cobalt the best. Certainly, electrolytic precipitation of metal from a ground coat onto a metallic base is in itself no important factor in adherence. It all depends on what metal is precipitated onto what kind and condition of base.

Kautz made a special case of iron by firing the ground coat in a vacuum and reports that he obtained no adherence. Of course he did not. It has been well known since the experiments of Cooke[3] in 1924 that a ground coat fired on clean steel in a vacuum will not adhere. Cooke found that the presence of a thin film of oxide of iron on steel is essential to produce wetting and uniform covering of the steel surface by the melting enamel. In any experiment in which this initial film of iron oxide is absent, conditions are entirely different from what they are in normal enameling practice, and thus no deductions can be made as to the mechanism of adherence in ordinary enameling procedure. It is to be noted that this initial film of iron oxide is dissolved in the early stages of the melting of the

* Received October 22, 1936.
[1] See footnote 5, p. 113.
[2] H. F. Staley, "Electrolytic Reactions in Vitreous Enamels and Their Relation to the Adherence of Enamels to Steel," *Jour. Amer. Ceram. Soc.*, 17 [6] 163–67 (1934).
[3] R. D. Cooke, "Effect of Furnace Atmosphere on the Firing of Enamel," *ibid.*, 7 [4] 277–81 (1924).

ground coat and bears no relation to the film of ferrous phase discussed later as being present in the fully melted enamel.

### III. Kautz Experiments in Gripping

Kautz also reports experiments in enameling (with a cobalt-bearing ground coat) various metals other than steel, ranging from chromium to gold and to steel in a vacuum and in an atmosphere of nitrogen. One-half of each sample plate was left smooth and the other half roughened by sandblasting or rubbing with an emery paper; none of the samples was pickled. Duplicates of a number of his sample plates were preoxidized. He concluded that the evidence presented by these experiments tends to show that gripping is not active in promoting adherence of vitreous enamels to metals. Lord has translated this statement into "effectively dismisses the idea of a gripping theory."

The art of enameling each metal involves a special technique and especially compounded enamels. The composition and methods of applying the blue ground coats now in use for sheet steel are the results of many years of experience and diligent research. That these enamels do not grip other metals (or steel under abnormal conditions) is no reason for saying that they do not grip steel when properly applied and fired.

After all, we must face the facts of life. If gripping plays no large part in the adherence of sheet-steel ground coats, then the industry is wasting millions of dollars each year in pickling steel to produce a surface structure suitable for gripping the metal by the ground coat. All the late developments in deep etching with the aid of sulfides and other chemicals are mistakes. Finally, the enameler who etches one piece of steel lightly and another deeply, enamels them with the same ground coat, drops the two pieces on a concrete floor, and finds the enamel adhering more tenaciously to the deeply etched piece is suffering from an optical illusion.

### IV. The Plating and Gripping Theory of Adherence

Since this discussion has mentioned several things that the theories of electrolytic precipitation and gripping do not imply, let us now consider some things that these two theories do imply as brought out in my paper.[2] In brief, that paper states that good pickling practice produces a structure on the surface of steel suitable for efficient gripping of the surface by a normal ground coat, fired in the normal manner. In the absence of metallic oxides from the ground coat, the molten enamel would dissolve off sharp corners and angular projections from the surface of the steel, thus converting it into a surface unsuitable for efficient gripping by the ground coat. When cobalt and nickel oxides are present in the ground coat in normal amounts, they are plated out of the molten ground coat onto the surface of the steel by the electrolytic action of the hot iron base. This plated metal protects the underlying surface from solution by the molten enamel, and thus the structure suitable for gripping, initially produced by pickling, is preserved. Small dendrites project from the surface of the plated metal. The cooled ground coat is mechanically bonded to the metal base by gripping the irregular surface. To a lesser degree, antimony oxide acts in the same way as nickel and cobalt oxides and promotes adherence. Although numerous other metals can be precipitated electrolytically from a molten ground coat, they do not promote adherence.

The theory that gripping is the fundamental cause of adherence and that the function of cobalt and nickel oxides in the ground coat is to plate out as metal, thus protecting from solution in the molten enamel the grippable surface structure produced by pickling, fits in well with present enameling practice and offers suggestions for further improvements in enamel technology. A few examples of these two functions are as follows:

#### (1) Better Pickling

Considerable progress in producing better adherence of ground coats has been made during the past few years by the more general use of deep etching through the aid of sulfides, nitric acid, and other chemicals.

#### (2) Plating the Pickled Metal before Enameling

The use of a nickel dip[4] is the most obvious example and is coming into general use.

Cobalt dips, or their equivalent,[5] and antimony

[4] J. E. Hansen and J. T. Irwin, "Use of a Nickel Dip in Enameling Practice," *Jour. Amer. Ceram. Soc.*, **18** [8] 225–29 (1935).

[5] J. E. Rosenberg, "Manufacture of Enamelware," U.S. Pat. 1,962,617, June 12, 1934; *Ceram. Abs.*, **13** [8] 202 (1934).

dips[6] have been tried and show promise. Carefully conducted experiments in electroplating with various metals should be carried out.

### (3) Preoxidation

The preoxidation experiments of Kautz suggest the possibility of protecting the grippable structure by a coating of ferrous oxide. Preliminary experiments in our laboratory with a bath of molten sodium nitrate indicate the possibility of developing a workable process for white ground coats along these lines.

### (4) Alloys

The production of enameling sheets bearing a surface film of a ferro alloy that will not dissolve in molten enamel is an inviting problem for metallurgists. It is already known that white ground coats adhere tenaciously to certain kinds of stainless steels when these are properly pickled.

### (5) New Methods of Operating Furnaces

Since the plating and gripping theory admits the necessity for an initial film of oxide of iron on the surface of the steel but does not call for any further oxidation of iron by the kiln gases,[7] the design or method of operation of continuous furnaces can well be altered so as to cut down the long period of exposure of ground coats to highly oxidizing gases with the consequent development of copperheads now so common. Slightly preoxidized ware could be fired in a neutral atmosphere as recommended by Martin.[8] It is entirely possible that sufficient oxidizing agents could be added to ground coats during grinding to bring about the necessary preliminary oxidation during the heating-up period in a neutral atmosphere.

### (6) White Ground Coats

According to this theory, one of the essentials for making a firmly adhering white ground coat is the production of an irregular metal surface that will not dissolve in the molten enamel. A large amount of work, especially in the use of various metallic dips and coatings along with deep etching, has been done along these lines and is still in progress. The other essential is the production of a ground-coat enamel that is sufficiently fluid to carry enough opacifier to render it opaque and at the same time fluid enough to permit the escape of gas bubbles and to flow readily into the interstices of the metal base.

Dietzel[9] has proved microscopically, analytically, and electrochemically that, during the fusion of blue ground coats, cobalt and nickel are plated out onto the steel. He states positively that the formation of an iron-oxide layer at the surface of the metal can not account for adherence. He suggests a modification of the plating and gripping theory proposed in the writer's paper. He states that because of the precipitation of cobalt and nickel on the iron, local currents are formed which produce a strong corrosion of the iron surface in spots; the enamel flows into the cavities and adheres. There is no doubt that such secondary electrolytic currents may be set up and produce minute pitting, but the writer is inclined to think that the preservation of the comparatively coarse grippable surface structure produced by good pickling is at least equally important. Otherwise, why does better pickling produce better adherence? It is to be noted that Dietzel too believes that gripping is the fundamental cause for adherence.

## V. Solution Bond Theory of Adherence

Kautz gives an able summary of the available knowledge as to the relations between iron and its various oxides at high temperatures. He then describes and illustrates by photomicrographs the progress of oxidation during the various stages of the firing of a normal blue ground coat. His explanations of the causes of "shiner-scale" and "copper-heads" are especially interesting.

On describing the normal stage of oxidation, that is, normal firing of the ground coat to produce best adherence, Kautz sees two things in his photomicrographs: (1) "a very irregular iron surface, with much undercutting along preferred paths and many irregular particles of the iron. . . . . completely detached from the base"; and (2) "a thin film of ferrous phase, approximately

[6] J. D. Tetrick, "A Study of White Ground Coats," *Jour. Amer. Ceram. Soc.*, **17** [11] 349–56 (1934).

[7] As cobalt and nickel oxides are plated out as metal, chemically equivalent amounts of iron are oxidized. This will produce considerable oxide of iron in the layer of enamel adjacent to the metal base, sufficient to give the advantage, if any, of an increased coefficient of thermal expansion in this very thin film.

[8] Wesley G. Martin, "Method of Enameling," U.S. Pat. 2,004,632, June 11, 1935; *Ceram. Abs.*, **14** [8] 184 (1935).

[9] Adolf Dietzel, "Adherence in Sheet-Iron Enamelware," *Sprechsaal*, **68** [1] 3–6, [2] 20–23, [3] 34–36, [4] 53–56, [5] 67–69, [6] 84–85 (1935); *Ceram. Abs.*, **14** [5] 107 (1935).

1/33,000 inch thick, between the iron on one side and the enamel glass on the other."

To believers in the gripping theory of adherence, it would seem natural and reasonable to say that the structure described by Kautz under (1) is a complete justification of the gripping theory and to hold that the minute film of ferrous stage is of no consequence. Kautz, however, ignores the presence of this irregular structure and simply states, without explanation or proof, that this film of ferrous stage is attached by means of a "solution bond" to the iron on one side and by means of a "solution bond" to the enamel glass on the other side. This looks like a difficult thing to believe and a harder thing to prove.

It would seem that Kautz has rather begged the question. He examines enameled samples that he knows have good adherence; among other things, he finds a thin film of ferrous phase present and concludes that, since it is present and the enamel adheres, it must be the cause of adherence. Of course, this is not necessarily true. It is entirely possible that the enamel would adhere better if this film were entirely absent.

## VI. The Chemical Union Theory of Adherence

Lord's own suggestion as to the mechanism of adherence causes the case to become even more complicated. He seems to doubt the existence of the minute film of ferrous phase that is the physical basis of the Kautz theory. He rejects the hypothetical "solution bonds" of Kautz and suggests the substitution of a still more hypothetical "chemical union." Thus, we finally lose all contact with reality and arrive in the realm of pure supposition.

## VII. Conclusion

It would be, obviously, a detriment to the development of enamel technology if the scientists and research men who are attempting to to solve the practical and very real problems of enameling should think themselves into that class described by Newton D. Baker as those who "discard the obvious as unreasonable and embrace the unreasonable because it is not obvious."

It is hoped that the foregoing discussion has been sufficient to show the intimate relation between the plating and gripping theory of adherence and present enameling practice. One part or the other of this theory constitutes a logical basis for several recent improvements in enamel technology. They form starting points for efforts at other improvements. During the course of centuries scientific theories have come to be evaluated in two ways: first, for their scientific accuracy, and second, for their inspirational value. It has often happened that the theories of the greatest inspirational value over a period of years have later been found wanting in exact scientific accuracy, but the advancement in the science due to their inspirational value has remained. This may happen to the modest plating and gripping theory of the adherence of enamels, but until a better proved and more workable theory of adherence is produced, it seems foolish to abandon the one that is the foundation of present enameling practice, that has brought about marked improvement in the recent past, and that holds promise for even greater improvement in the future.

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## Discussion of Staley Paper*

BY R. M. KING

Staley's idea that rough surface enhances adherence except as it increases the surface is rapidly losing ground. This is true even as applied to wood and glue. In fact, there is an abundance of evidence to show that the smoother the surface the greater the adherence.

I agree with Staley that Kautz has accumulated little evidence to support his theory. He has pointed out that according to the phase-equilibria diagram, certain phases are supposed to be present. He has not identified any of these phases, however, by positive methods, such as petrographic and X-ray methods. Furthermore, he has based his theory of adherence on a compound which is unstable at ordinary temperatures.

In paper No. XIII,[1] we have shown by X-ray methods that FeO, Fe, and $Fe_3O_4$ are present in the normally fired enamel. It is possible that one, two, all, or none of these compounds are functioning as adhering agents. Hence, there

* Received March 2, 1937.

[1] R. M. King, "A Review of the Theoretical Explanations for the Formation of Metal Particles in Cobalt Ground Coats and Some Pertinent Experiments," *Jour. Amer. Ceram. Soc.*, **20** [2] 53–55 (1937).

remains the academic question: What is sufficient proof? First, Kautz should give stronger evidence that FeO is present, and second, he should show that there is no adherence when FeO is absent.

It has been shown[2] that a cobalt ground coat will not adhere when fired *in vacuo* and that FeO is present and Fe absent in this enamel. This is the status of proof of the dendrite theory. It is a step in advance of Kautz's theory, though not necessarily sufficient proof.

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## Reply to Staley's Discussion*

By J. O. Lord

Staley's written discussion was submitted at a late date after the presentation of my original paper.[3] Since the context of the written discussion is quite different from that of the verbal discussion that Staley made at the March meeting, it is necessary to include a reply to the written discussion. A separate statement by King is also added to this somewhat lengthy discussion. Only two points in Staley's discussion will be dealt with.

First, he states that "if gripping plays no large part in the adherence of sheet-steel ground coats, then industry is wasting millions of dollars each year in pickling steel to produce a structure suitable for gripping the metal by the ground coat."

This is entirely possible. There is evidence to show that cobalt ground coat, applied on black sheet, adheres well. An experiment to demonstrate this was mentioned in Kautz's paper. The purpose of pickling, however, is not only to produce a rough surface but also to remove iron oxide. This would make it unnecessary if Kautz's theory regarding the necessity for an oxide layer is correct.

As a matter of fact, so many diverse effects have been observed in pickling and sandblasting that industry is probably justified in being unwilling to change its practice until more definite experimental data are available.

The second point in Mr. Staley's remarks is that in "the substitution of a still more hypothetical 'chemical union' . . . . . we finally lose all contact with realism and arrive in a realm of pure supposition." Naturally we are in a realm of pure supposition as long as all theories on the subject are debatable. Staley would nail his enamel on; Kautz would stick it on with ferrous oxide cement; and Lord thinks that it will stick without either nails or cement. This seems to be the situation that now faces the reader of this discussion.

The theories of Lord and Kautz are really not so far apart as Kautz seems to think. I have said that I would like to dispense with the necessity for a layer of ferrous oxide and that it seemed to me unnecessary, but I freely admit the necessity of ferrous oxide dissolved in the enamel phase, even to the point of saturation at the interface. But even if the separate ferrous-oxide phase is necessary, the problems still remain of finding how the ferrous oxide sticks so well to the iron and how and when it sticks well to the glass. These problems are still of practical importance, particularly in connection with related problems of reboiling and flaking. The problem of the rôle of cobalt oxide in the enamel phase has also yet to be solved.

[2] R. M. King, "X, The Iron Oxide Layer in Sheet Steel Ground Coats," *ibid.*, 17 [7] 215–19 (1934).

* Received March 2, 1937.

[3] See p. 111, this issue.

# PURIFICATION OF KAOLIN: SOME DATA ON THE CLASSIFICATION OF QUARTZ AND MUSCOVITE*

By Hewitt Wilson† and George J. Middleton‡

ABSTRACT

This report covers a review and correlation of previous theoretical and laboratory research of falling particles with some data on the settling of quartz and muscovite grains of variable shape and particle size in water, with and without vacuum and alkali treatment. Stokes' law and Richards' data were checked. The greatest factor which produced a variation in rate of fall was incomplete dispersion of the particles. Complete dispersion with alkali gave the best correlation with theoretical calculations.

## I. Introduction

Few data are available concerning the most important phase involved in the purification of kaolin or china clay, that is, the settling velocities of the different ingredients. This report attempts to correlate some of the previous work, reviews the principles involved, gives a few preliminary data on the relative rates of settling quartz and muscovite in quiet water, and seeks to evaluate the different factors that vary the rate of settling.

White kaolin or china clay is produced from the original kaolin rock by removal of quartz, muscovite, and a small amount of other heavy pegmatitic minerals. Three general methods of purification are in service at present, (1) pneumatic methods in Georgia and South Carolina, where the kaolin rock contains less than 10% impurities[1]; (2) a centrifugal machine for aqueous suspensions in Vermont[2]; and (3) the oldest and most common method, differential settling in comparatively quiet streams of water. In method (3), the kaolin rock is dispersed in water by blunging. The dilute suspension is passed through settling troughs, tanks, or pans, where the larger particles settle first in swifter streams and the fine sand and mica in very slow-moving currents. The coarse sizes are removed easily, but a classification of the fine quartz, muscovite flakes, and kaolin particles involves careful regulation of current and viscosity. It has been found that the most complete separation can be made in an alkaline solution in which the kaolin particles are completely dispersed or deflocculated.

The present study undertook a preliminary survey of the settling of the mineral ingredients in still water only; the application to current classification will be made in later reports. Likewise more attention was given the sizes of grain near the commercial maximum for kaolin, those from 0.02 to 0.08 millimeter in diameter, because the greatest difficulties of classification are found in this range.

(1) The results of this study checked those of Richards[3] for angular quartz particles ranging in diameter from 4.0 to 0.15 millimeter or in that range between Rittinger's eddying resistance and Stokes' viscous resistance.

(2) Stokes' settling curve was paralleled for the finer sizes down to 0.02 millimeter in diameter when different constants were used. The settling of fine quartz and muscovite between 0.06 and 0.02 millimeter in diameter in alkaline solutions roughly followed the equation, $V = 1500D^2$, where the velocity is given in millimeters per second and diameters are given in millimeters. Muscovite particles between 0.15 and 0.06 millimeter in pure water settled in accordance with the curve, $V = 374D^2$.

(3) While the rates of fall of fine mica and quartz were similar, the rate for mica coarser than 0.06 was much slower than that for the same sized quartz particles.

(4) The average rate of fall for different-shaped particles between 28- and 240-mesh, in comparison with round particles of quartz, was as follows: 89% for subangular quartz shapes, 81% for angular quartz, and 25% for muscovite particles.

(5) Alkaline solutions gave more consistent re-

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[1] Hewitt Wilson and J. A. Cunliffe, "Refining of Pacific Northwest Kaolins by Air Flotation," *Jour. Amer. Ceram. Soc.*, **16** [3] 154–62 (1933).

[2] Vermont Kaolin Corporation, Bennington, Vt.

[3] R. H. Richards, "Velocity of Galena and Quartz Falling in Water," *Trans. Amer. Inst. Min. Eng.*, **38**, 210–35 (1907).

sults for quartz and mica than nearly pure tap water both with and without de-airing; and kaolin particles, dispersed by the alkali, gave a cleaner separation from the quartz and mica.

## II. General Theories of Kaolin Purification

### (1) The Mineral Properties

The purification of kaolin is based principally on the differential settling or rate of fall in a fluid medium, such as water or air, of particles having similar densities but different sizes and shape of grain. The quartz ($SiO_2$, specific gravity from 2.6 to 2.66) particles are the largest, and range in diameter from $^1/_2$ inch (127 mm.) to near colloidal size (0.0001 mm.). Their shape is usually angular but may be rounded. Muscovite ($K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$, specific gravity 2.76 to 3.00) varies in particle shape and size. In residual kaolin rock, the mica may occur as small booklets, angular in shape and of equal diameter in three dimensions. When such kaolin rock, however, has been disintegrated by natural or artificial means, these booklets are broken into very thin plate-like leaves. Diameter measurements made in two dimensions only are therefore unreliable for the calculation of settling rates, if no attention is given to thickness, weight, or volume of the particle. Sericite, having the same composition as muscovite, is a silvery-white variety of muscovite occurring in minute silky scales and fibrous bunches as a common alteration product of the feldspars.

Kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) is similar to muscovite in alumina and silica content, with a higher water content and without alkali. Kaolinite contains 39.8% $Al_2O_3$, 46.3% $SiO_2$, and 13.9% $H_2O$. Muscovite, when theoretically pure, contains 38.5% $Al_2O_3$, 45.2% $SiO_2$, 4.5% $H_2O$, and 11.8% $K_2O$. The muscovite content of a kaolin, therefore, is not indicated by a chemical analysis unless a determination is made for alkali, which likewise can be assigned to feldspar. Kaolinite particles are very minute. In commercial kaolins, plate-like crystal remnants similar to the finest muscovite or sericite particles are found, and it is difficult therefore, to adjust the velocity of the settling medium to separate the smallest mica particles from the larger kaolinite and kaolin grains. Several world-famous commercial kaolins contain 1.0% alkali, indicating 5.9% unaltered feldspar or 8.5% muscovite remaining in the washed kaolin as an impurity. Ross and Kerr[4] describe a mica-like material with a birefringence nearly the same as that of muscovite occurring in many kaolin deposits. It is not muscovite but probably a clay that is similar to kaolinite having one instead of two molecules of water. The presence of this material adds more confusion to an accurate mineral classification of the kaolin rock.

The purification of any kaolin rock after dispersion in water consists of settling the rapidly falling coarse quartz and mica, followed by regulation of the stream flow and time of settling to separate certain sizes of the finer particles, leaving mica in the kaolin portion and *vice versa*. Many grades of kaolin are found on the market, from the poorly washed materials in which mica and sand particles can be concentrated easily in the bottom of a dilute suspension to the near-colloidal clay masses in which very few particles can be distinguished except by the highest magnifications.

For fired ceramic purposes, it is important to remove the small mineral particles which contain iron oxide, as essential constituents or as impurities, such as magnetite ($FeO \cdot Fe_2O_3$), ilmenite ($FeO \cdot TiO_2$), anatase and rutile ($TiO_2$), zircon ($ZrO_2 \cdot SiO_2$), monazite ((Ce, La, Di) $PO_4$), topaz ($(AlF)_2\ SiO_4$ with $(Al \cdot OH)_2\ SiO_4$), cassiterite ($SnO_2$), tourmaline ($(R_9Al_3(B \cdot OH)_2\ Si_4O_{19}$), staurolite ($FeO \cdot 2Al_2O_3 \cdot 2SiO_2 \cdot H_2O$), etc., which have specific gravities greater than 2.85. These are not very abundant and usually are finer than 20-mesh. While these minerals do not show in the dry powdered kaolin, they are magnified by fusion, melting, or vitrification at high temperatures, and they must be removed completely for the best grades of ceramic ware, since a single black speck often will spoil an expensive article. The high density of these minerals causes them to settle with the larger grains of quartz, and both can be removed readily from a suspension that has been diluted sufficiently to reduce the density and viscosity values nearly to those of water.

### (2) Theory of Free Settling

The particles in kaolin washing fall under free-settling conditions, that is, the hindrance of other particles in dilute suspensions is very small. Because washing usually is accomplished in a horizontal current of water, the disturbance of eddy currents tends to keep the particles in suspension

[4] C. S. Ross and P. F. Kerr, "The Kaolin Minerals," *U. S. Geol. Surv. Prof. Paper*, No. 165-E, p. 172 (1931). See also *Jour. Amer. Ceram. Soc.*, 13 [3] 151–60 (1930).

for a greater length of time than in quiet water.

The velocity of solid bodies falling or settling in a fluid medium such as water or air varies[5] (1) directly as the square of the diameter when these are small; (2) directly as the difference between the specific gravity of the solid body and that of the fluid medium; (3) with the shape of the particle (those most nearly spherical will fall faster than those of tabular or plate-like shape); and (4) inversely with the viscosity of the medium (the increased resistance to fall is relatively greater with the smaller particles).

The resistance to fall varies as the one-half power of the velocity when the latter is very small, as the square when the velocity is large, and as some intermediate power or powers in the transition range. Air bubbles on the particles and magnetization also affect the rate of settling.

When the velocity of fall is low, little disturbance is generated in the fluid by the passage of the particle; the film or layer of fluid in contact with the particle moves with it while the body of the fluid a short distance away is at rest. Substantially all of the resistance to movement is due to the viscosity of the fluid. Such resistance is called "viscous resistance."

When the velocity of fall is high the principal resistance to its motion is that offered by the fluid to bodily displacement from the path of the particle. The kinetic energy imparted to the fluid is dissipated in eddying and turbulence. The effect of the viscosity of the medium is relatively small. This resistance is variously called "eddying resistance" or "turbulent resistance." In both cases acceleration decreases rapidly, and the body quickly attains a uniform terminal velocity.

(*a*) *Viscous Resistance:* Taggart[6] states,

> Stokes in 1850 deduced theoretically a formula for the terminal velocity of a small solid sphere falling freely under the influence of gravity in a viscous fluid. At the beginning of such fall, the pull of gravity on the sphere exceeds the resistance of the fluid and the particle is accelerated. With increasing velocity, the frictional or viscous resistance of the fluid increases until a point is reached where the resistance is just equal to the gravity pull. Thereafter the body falls at a uniform velocity.

According to Stokes, at this stage

$6\pi krV$ = the resistance.
$4/3\pi r^3g(d_1 - d)$ = gravitational pull on the sphere.

[5] R. H. Richards and C. E. Locke, Ore Dressing, 2d ed., p. 127. McGraw-Hill Book Co., New York, 1925.
[6] A. F. Taggart, Handbook of Ore Dressing, p. 551. John Wiley & Sons, Inc., 1927.

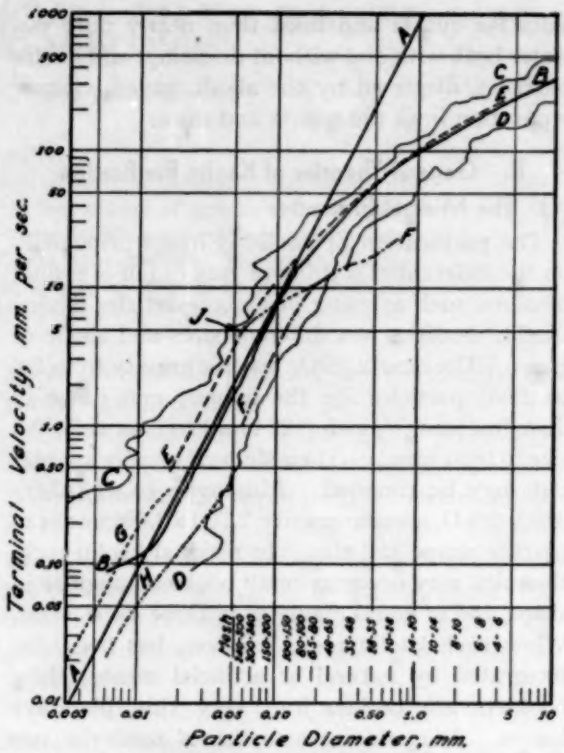


FIG. 1.—Rates of falling in quiet water of various sized particles of quartz and muscovite in comparison with Stokes' law. Line *A–A* represents Stokes' law; curve *B–B*, average data from Richards' experiments; *C–C*, Richards' curve of maximum velocities; *D–D*, Richards' curve of minimum velocities; *E–J–E*, average data from the present study for angular quartz; *J–F*, average data from this study for muscovite in alkaline solution; *F–F*, average from the present study for muscovite in pure water; *G*, average for kaolin particles in distilled water from Schurecht's study; and *H*, average for kaolin particles from Weigel's study.

The resistance equals the gravitational pull if the terminal velocity has been attained, and the solution of the equation for velocity gives

$$V = \frac{2r^2g(d_1 - d)}{9k} \quad \text{(Stokes' law)}$$

Where $V$ = velocity of settling (cm./sec.).
$r$ = radius of particles (cm.).
$d_1$ = density of particle.
$d$ = density of liquid.
$g$ = gravity constant (981).
$k$ = viscosity of fluid (about 0.01 for water).[7]

When water is the medium, $k$ and $d$ become constants and the formula can be stated as

$$V = KD^2(d_1 - 1)$$

Where $D$ = diameter.
$K$ = 545 from Stokes' formula above (when velocity is mm./sec. and diameter in mm.).

[7] The viscosity of water at 0°C is 0.01792; 5°, 0.01519; 10°, 0.01308; 15°, 0.01140; 20°, 0.01005; 25°, 0.00894; 30°, 0.00801; 40°, 0.00656; 50°, 0.00549; 75°, 0.00380; 100°, 0.00284. See Handbook of Chemistry and Physics, 14th ed., p. 823. Chemical Rubber Pub. Co., Cleveland, Ohio, 1929.

The equation for the nonmetallic minerals of this study can be stated as

$V = 900D^2$ (for quartz, specific gravity, 2.65).
$V = (960 \text{ to } 1090)\ D^2$ (for muscovite mica, specific gravity 2.76 to 3.00).
$V = 872D^2$ (for kaolin, specific gravity 2.6).

Figure 1 shows the curve of Stokes' law (line *A–A*) compared with experimental data.

The data of Richards and his co-workers[8] published in 1909 have been used by all subsequent mining writers throughout the world. The average of 100 settling observations was taken for the sizes between 11.93 and 0.32 millimeter. The velocities of the particles between 0.369 and 0.00589 millimeter were determined by elutriation and the diameters were measured microscopically. The average diameters of ten microscopic fields were used. Table I gives the data from the smoothed curves plotted from Richards' average results. The values of $K$ range from 1600 when the diameter is 0.006 millimeter to 2.2 when the diameter is 10.0 millimeters. Richards suggested a $K$ value of 424 for velocities below the critical velocity of 28 millimeters per second for quartz, which he states corresponds to a critical diameter of 0.20 millimeter. Taggart[9] used 450 as the value of $K$ between 0.16 and 0.0015 millimeter diameter. Finkey [10] used 545 for $K$ between 0.02 and 0.22 millimeter.

TABLE I

RELATION BETWEEN SIZE OF QUARTZ PARTICLES AND THEIR FREE-SETTLING VELOCITIES*

| Viscous resistance | | | Intermediate phase | | | |
|---|---|---|---|---|---|---|
| Diameter (mm.) | Velocity (mm./sec.) | Constant $K$ | Diameter (mm.) | Velocity (mm./sec.) | Constants $K$ | $C$ |
| 0.006 | 0.095 | 1600 | 0.16 | 17.7 | 418 | 34 |
| .008 | .105 | 995 | .20 | 22.5 | 340 | |
| .010 | .110 | 667 | .25 | 28.0 | | 44 |
| .012 | .125 | | .30 | 33 | | |
| .014 | .150 | | .4 | 44 | | |
| .016 | .180 | | .5 | 53 | | |
| .018 | .225 | | .6 | 63 | | |
| .020 | .280 | 424 | .7 | 72 | | |
| .022 | .335 | | .8 | 81 | | |
| .024 | .405 | | .9 | 87 | | |
| .026 | .495 | | 1.0 | 94 | 57 | 74 |
| .028 | .590 | | 1.1 | 100 | | |
| .030 | .685 | 462 | 1.2 | 106 | | |
| .032 | .780 | | 1.3 | 112 | | |
| .034 | .870 | | 1.4 | 118 | | |
| .036 | .965 | | 1.5 | 125 | | |
| .038 | 1.055 | | 1.6 | 131 | 31 | 81 |
| .040 | 1.145 | 434 | | | | |
| .042 | 1.235 | | | | | |
| .044 | 1.330 | | | | | |
| .046 | 1.420 | | Eddying resistance | | | |
| .048 | 1.51 | | 1.7 | 137 | | 82 |
| .050 | 1.70 | 412 | 1.8 | 144 | | |
| .06 | 2.35 | | 1.9 | 149 | | |
| .07 | 3.15 | | 2.0 | 155 | 24 | 85 |
| .08 | 4.30 | | 2.1 | 160 | | |
| .09 | 5.75 | | 2.2 | 164 | | |
| .10 | 7.5 | 455 | 2.5 | 176 | | |
| .11 | 9.3 | | 3.0 | 195 | | |
| .12 | 11.3 | | 3.5 | 210 | | 87.5 |
| .13 | 13.4 | | 4.0 | 225 | | |
| .14 | 15.2 | | 5.0 | 250 | | |
| .15 | 16.5 | 445 | 6.0 | 274 | | |
| | | | 7.0 | 297 | | |
| | | | 8.0 | 318 | | |
| | | | 9.0 | 340 | | |
| | | | 10.0 | 359 | 2 | 89 |
| | | | 11.0 | 377 | | |
| | | | 12.0 | 393 | | 89 |

* The data were taken from the smoothed curves, plotted from Richards' average results (see footnote 8(*a*)).

Curve *B–B*, Fig. 1, shows the average of Richards' data from the finest particles to those having a diameter of 6 millimeters. Curves *C–C* and *D–D* show Richards' data for the maximum and minimum velocities, respectively. The curves are broken or overlapping between 0.3 and 0.5 millimeter.

Schöne[11] suggested the following empirical formula to calculate the diameter of grains carried by a given velocity of rising water as used in elutriation apparatus:

$$D = 0.0518 \frac{V^{(0.838)}}{S - S_1}$$

Where $D$ = diameter (mm.).
$V$ = velocity (mm./sec.).
$S$ = specific gravity of the particles.
$S_1$ = specific gravity of the suspension or slip.

This formula can be reduced to the following when quartz of specific gravity 2.65 is used with water:

$$D = 0.0314 V^{(0.838)}$$

Schurecht[12] found that Schöne's formula was satisfactory when used in the elutriation of fourteen china clays with distilled water plus NaOH for complete dispersion and when the diameters were checked by microscopic measurements. The average data are given in Table II.

The velocities given in Table II are not the rates of settling but the velocity of the rising column of water which will carry these diameters.

[8] (*a*) R. H. Richards, Ore Dressing, Vol. 3, pp. 1422, 1426, 1427, and Vol. 4, pp. 2003–2006. McGraw-Hill Book Co., 1909.
(*b*) R. H. Richards and C. E. Locke, Ore Dressing, 2d ed., pp. 127–35. McGraw-Hill Book Co., New York, 1925.

[9] A. F. Taggart, *loc. cit.*, p. 553 (footnote 6).

[10] J. Finkey, Scientific Fundamentals of Gravity Concentration, 1927 (translation by C. O. Anderson and M. H. Griffitts, *School of Mines and Metallurgy, Univ. of Mo. Tech. Ser.*, 11 [1] 1–75 (Nov., 1930); *Ceram. Abs.*, 9 [7] 597 (1930).

[11] E. Schöne, Ueber Schlämmanalyse und einen neuen Schlämmapparat (Elutriating Analysis and a New Elutriating Apparatus), Berlin, 1867.

[12] H. G. Schurecht, "Elutriation Tests on American Kaolins," *Jour. Amer. Ceram. Soc.*, 3 [5] 355–78 (1920).

The rate of settling therefore is less than the above velocities. Curve *G*, Fig. 1, shows the relation of Schurecht's data to Stokes' law and other experimental results.

TABLE II

VELOCITY OF WATER FLOW VERSUS DIAMETER OF CHINA CLAY (SCHURECHT)

| | | | | |
|---|---|---|---|---|
| Velocity of flow (mm./sec.) | 0.347 | 0.180 | 0.059 | 0.0197 |
| Calculated diameter (mm.) Schöne formula) | 0.0154 | 0.0105 | 0.0052 | 0.0026 |
| Diameters with distilled water (mm.) (microscope) | .0177 | .0098 | .0055 | .0033 |
| Diameters with tap water* (mm.) (microscope) | .0060 | .0038 | .0027 | .0018 |
| Richards' constant $K$† | 672 | 1140 | 1181 | 1095 |

* Tap water coagulated the grains and caused them to settle as larger masses.
† Using distilled water.

Weigel[13] likewise used Schöne's formula and Schurecht's apparatus for china clays with the results given in Table III.

TABLE III

COMPARISON OF AVERAGE DIAMETERS OF ELUTRIATED FRACTIONS CALCULATED BY SCHÖNE'S FORMULA, WITH MICROSCOPIC COUNT AND MEASUREMENT (WEIGEL)

| Elutriation can | 1 | 2 | 3 | 4 | Overflow |
|---|---|---|---|---|---|
| Upward velocity (mm./sec.) | 0.393 | 0.200 | 0.067 | 0.022 | Overflow |
| Calculated diameters (mm.)* | .0173 | .0112 | .0056 | .00276 | |
| Observed diameters (10 samples of china clay)† | | | | | |
| Max. | 0.0543 | 0.0367 | 0.0155 | 0.0090 | 0.0044 |
| Min. | .0414 | .0211 | .0066 | .0026 | .0017 |
| Av. | .0478 | .0283 | .0116 | .0059 | .0026 |

* Schöne's formula with a specific gravity of 2.60.
† Average size determined by microscopic count and measurement; calculated on basis of specific surface.

Curve *H*, Fig. 1, shows Weigel's data in comparison with Stokes' law and other experimental results.

Roller[14] used Stokes' law in the separation of dry particles in an air analyzer. He states,

> It was found that Stokes' law is closely obeyed. In each fraction there is a small percentage overlap of not more than a few microns, a result to be expected because of the irregularity in shape and surface of the grains, inhomogeneity of the density of the grains, error in measurement under the microscope, and incompleteness of the fractionations. The microscopically determined surface-mean diameter of the fractions is closely equal to the mean of Stokes' law limits.

(*b*) *Intermediate-Size Particles between Viscous and Eddying Resistance:* Richards[15] found that the formula, $V = 89\ D^{0.67}$, applied to the larger diameters, while Taggart[9] suggested the use of $V = 95D^{0.83}$ for quartz particles between 0.16- and 1.60-millimeter diameter.

(*c*) *Eddying Resistance:* Richards[15] gives the following derivation:

> Stokes' equation is derived on the assumption of small velocity and a resistance due entirely to viscosity proper, and it is known not to hold above a certain "critical velocity" when the resistance due to eddying motion set up in the fluid becomes appreciable and important. For such high velocities, a complete theory seems to be almost impossible, but Sir Isaac Newton pointed out that the resistance might be expected to vary as the square of the velocity. In other words, $R = kV^2$, where $R$ is the resistance to motion and $k$ is a constant. Evidently, when dynamic equilibrium is attained, $R$ is just equal to the effective weight of the particle in the liquid. The effective weight has been shown above to be $D(d_1 - 1)$.[16] Substituting this value for $R$ in the equation above, we have $D(d_1 - 1) = kV^2$, from which we get, by extracting the square root, Rittinger's formula,[17]

$$V = C\sqrt{D(d_1 - 1)}$$

> using $C$ outside the radical in place of $1/k$ inside.

The value of $C$ given by Richards[15] was 87; Taggart[9] used 92 for particles larger than 1.6 millimeters and Finkey[10] suggested 77. Table I gives the values for $C$ actually derived from Richards' data. They range between 82 and 89.

Rubey[18] calculated the rates of fall with different methods of water contact with mineral particles. If it is assumed that each droplet is

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[13] W. M. Weigel, "Size and Character of Grains of Nonmetallic Mineral Fillers," *U. S. Bur. Mines Tech. Paper*, No. 296 (p. 5), 44 pp. (1924).

[14] P. S. Roller, "Separation and Size Distribution of Microscopic Particles," *ibid.*, No. 490 (p. 45), 46 pp. (1931).

[15] R. H. Richards, Ore Dressing, Vol. 3, p. 1425.

[16] Richards' "effective weight" is equal to the height, $h$, of a square column of water which just balances a submerged cube of mineral of side, $D$; that is, the weight of the mineral cube minus the weight of an equal volume of water or its buoyant force. "Therefore the velocity due to $h$, if rising, is able to prevent the grain from falling; or, in other words, it is the velocity of the fall of the grain." $h$ is determined from the following equation:

$$hD^2 = D^3d_1 - D^3$$
$$h = D(d_1 - 1).$$

[17] Rittinger derived this same equation by a different method. He substituted $D(d_1 - 1)$ for $h$ in the equation for falling bodies, $V = \sqrt{2gh}$ and the constant $C$ for $\sqrt{2g}$.

[18] W. W. Rubey, "Settling Velocities of Gravel, Sand, and Silt Particles," *Amer. Jour. Sci.*, [5] 25, 325–38 (1933).

perfectly reflected from the bottom of a sphere, a theoretical formula similar to Rittinger's is found:

$$V = \sqrt{\frac{4g(d_1 - d)r}{3d}} \text{ (centimeters).}$$

When this changed to a form similar to Rittinger's, $C$ equals 103. But if each water droplet is assumed as sliding off instead of rebounding, the settling velocity of the sphere will be twice as great. The actual velocity lies somewhere between the two extremes, since some of the water is reflected and some deflected. Few of the water particles strike directly against the surface of an irregularly shaped mineral particle; most of them are crowded off by the film of water adhering to the surface and by a cone of dead or swirling water built up directly in front of the particle.[18]

Rubey also derived a general formula for all three conditions, *i.e.*, viscous resistance and intermediate and eddying (impact) resistance:

$$V = \frac{\sqrt{\frac{20}{3} \cdot g \cdot d(d_1 - d)D^3 + 360{,}000k^2} - 600k}{d \cdot D}$$

This can be simplified for quartz at 16°C as follows:

$$V_q = \frac{6.6}{D}\left[\sqrt{247.47D_q^3 + 1} - 1\right]$$

The use of formulas for data of this nature is questioned, and even Richards stated,[19] "In fact, the values of the velocity over the whole range can be read off from the plot as accurately and more readily than they could be computed from the formulas."

## III. Present Investigation

### (1) Methods of Measuring Rate of Settling

The coarse particles of quartz and mica were classified by screening, and the time of fall, for a measured distance, in water at room temperature (20° to 25°C) was determined by a stop-watch. Five sets of readings were averaged to produce the settling times for the fastest, the slowest, and for 90% (approximately) of the particles.

For the coarse particles, a glass tube, 140 centimeters long with an inside diameter of 5.3 centimeters, was held in a vertical position with the lower end submerged in a large pan of water. This corresponds to Richards' tube for intermediate sizes and was longer than his decantation tube for the finest sizes.[20] E. M. Finkey showed that a quartz particle with a diameter of 1 millimeter reaches a constant velocity after falling 1 centimeter in water in 0.08 second. He states that "for practical purposes the final or end velocity instead of falling velocity can be used in computations when the mineral grain, whose diameter is less than 1 millimeter, falls more than 60 millimeters in water." A rubber stopper at the bottom held the column of water when the top was open for charging the sample, but after the top was closed with a similar rubber stopper, the bottom was opened and air pressure sustained the

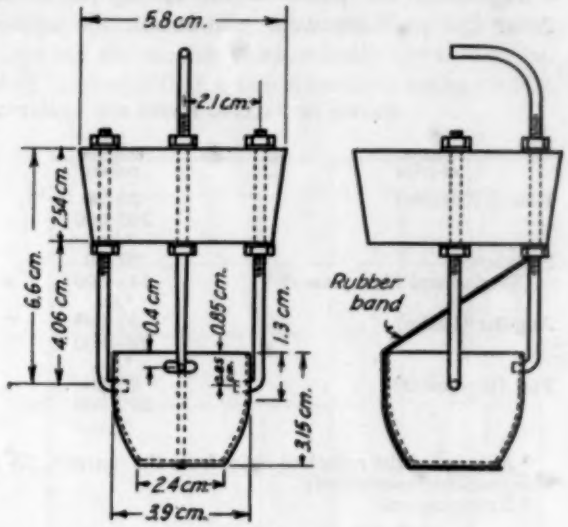


FIG. 2.—Cup for starting large grains.

column of water. Settled particles were caught in evaporating dishes and watch glasses below the tube.

The particles were released inside the tube after the upper stopper was in place. A small metal crucible was suspended within the tube and hinged at the top on two small brass rods which were attached to the stopper (Fig. 2). A rubber band, with one end fastened to the stopper, was stretched over the bottom of the crucible from a fixed point on the rubber stopper and was fastened to the opposite side of the crucible when in the vertical position. The crucible was held vertically for charging by a third brass rod, whose bent end engaged a hole in the top of the crucible and also projected through the stopper. By turning this rod, the crucible was released, the rubber band snapped the crucible to the inverted position and discharged the particles downward. Since this movement produced considerable agitation in the

[18] R. H. Richards, Ore Dressing, Vol. 3, p. 1426.
[19] See pp. 36 and 103 of footnote 19.

top of the tube, it was used only for the largest particles.

Comparative tests were made with a large tank about 2 feet in diameter. No difference was noted between the settling rates of the same coarse particles in the two chambers.

The fine subsieve particles with very slow rates of fall were introduced by washing them from a small dish through a 1.5-inch grid made of $^1/_8$-inch diameter glass tubes bound together on a coarse screen and inserted into the top of the tube. This grid nearly eliminated the eddy currents and straightened the paths of the falling particles. After the particles were introduced, the upper stopper was replaced, the lower stopper withdrawn, and watch glasses were placed at the bottom of the tube for periodic removal of the settled grains.

TABLE IV

RATIOS OF FALLING RATES FOR LIMITING SIZES OF SILICA AND MUSCOVITE PARTICLES

| Shape of grain | Size of grain (mesh) | Max. rate (ratio) | Rate of 90% of particles | Min. rate (ratio) | Max. difference (mm./sec.) |
|---|---|---|---|---|---|
| Round (Ottawa) | 20–28 | 1.35 | 1.00 | 0.90 | 36 |
| | 240–300 | 2.34 | 1.00 | .47 | 12 |
| | *Av. | 1.45 | 1.00 | .78 | 24 |
| Subangular (Belgian and New Jersey) | 20–28 | 1.31 | 1.00 | .91 | 58 |
| | 240–300 | †2.01 | †1.00 | †.45 | 11 |
| | *Av. | 1.46 | 1.00 | .75 | 24 |
| Angular (Idaho) | 20–28 | 1.26 | 1.00 | .88 | 34 |
| | 240–300 | 2.22 | 1.00 | .53 | 10 |
| | *Av. | 1.45 | 1.00 | .78 | 20 |
| Flat (muscovite) | 20–28 | 1.49 | 1.00 | .21 | 28 |
| | 240–300 | 4.55 | 1.00 | .46 | 5 |
| | *Av. | 2.57 | 1.00 | .29 | 14 |

* Average of the complete series from the coarsest, 20- to 28-mesh, to the finest, 240- to 300-mesh quartz and muscovite particles, respectively.
† Extrapolated.

### (2) Preliminary Tests of Coarser Particles

(*a*) *Variation of Falling Rate:* Richards' data,[21] shown in Fig. 1, indicate a considerable variation in the settling rates between particles having approximately the same size. This difference shown by the maximum curve, *C–C*, and the minimum curve, *D–D*, is less with the coarser particles and becomes quite large with the finer particles. For the larger particles, he states, "it will be noted that the slower grains are nearly all long or flat and that the faster grains are nearly all cubical."

While irregularities in shape and route or style of falling accounted for most of the variations in rate, it was noted that some grains fell at different rates and no apparent difference could be noted in their shape, appearance, or path of fall. A summary was made of the variations for round Ottawa, subangular Belgian and New Jersey, and angular Troy (Idaho) quartz and muscovite particles between the sizes, 20- to 28-mesh and 240- to 300-mesh, shown in Table IV, taken from the curves of Figs. 3, 4, 5, and 6.

While the ratios of Table IV indicate a greater variation in the falling rates of the finer quartz particles than of the coarse, the actual maximum difference between the fast and slow is less with the finer particles, as shown in the last column. The shape of the quartz grains did not cause this irregularity, since the average ratios and average maximum differences were similar. The muscovite flakes showed less variation but greater ratio differences because of their small falling rates. The variation (as shown in Figs. 1, 3, 4, 5, and 6) is greater than that which can be attributed to the difference due to the size limits formed in screening.

The muscovite particles (Fig. 6) finer than 80-mesh were produced by screening the ball-milled, ground product from selected muscovite flakes, cleaned from quartz and kaolin. The grinding action probably reduced the variation of thickness found in the larger underground particles. The rate of fall for the particles finer than 80-mesh was slower than that obtained in later experiments with alkaline solutions.

(*a-1*) *Variation of Falling Rate with Shape of Particle:* Richards' quartz sand[22] was "plain white quartz" from an unknown source and was crushed

[21] R. H. Richards, "Velocity of Galena and Quartz Falling in Water," *Trans. Amer. Inst. Min. Eng.*, 38, 218 (1907).

[22] See p. 213 of footnote 21.

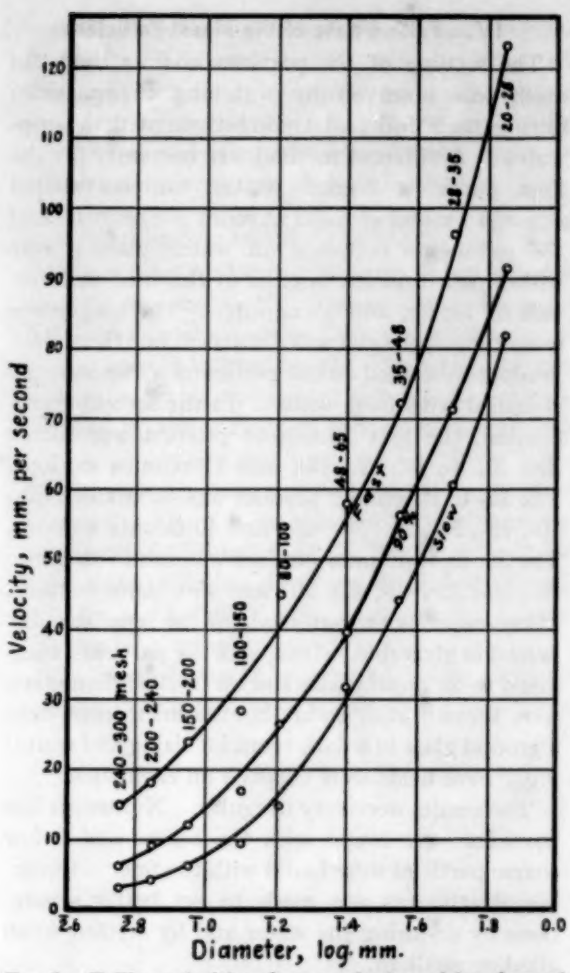


FIG. 3.—Falling velocities of screen-sized particles of round Ottawa sand.

to size and therefore undoubtedly was quite angular. Curves made from preliminary data giving the rates of settling for round, subangular, and angular particles between the sizes 28 to 35 and 240 to 300 showed that the settling rates of the finer sizes were similar but with the larger sizes there was a divergence when the shape was different. Table V shows the ratios of settling from the smoothed curves of Fig. 7.

TABLE V

RATIOS OF FALLING RATES FOR DIFFERENTLY SHAPED PARTICLES OF QUARTZ AND MUSCOVITE IN WATER

| Size of particle (mesh) | Round particles (rate, mm./sec.) | Subangular particles (rate, ratio to round) | Angular particles (rate, ratio to round) | Muscovite particles (rate, ratio to round) |
|---|---|---|---|---|
| 20– 28 | 91.5 | 1.08(?) | 0.90 | 0.25 |
| 28– 35 | 71.5 | 0.88 | .83 | .23 |
| 35– 48 | 57.0 | .77 | .74 | .26 |
| 48– 65 | 40.0 | .87 | .78 | .31 |
| 65– 80 | 30.0 | .85 | .78 | .32 |
| 80–100 | 27.0 | .85 | .72 | .33 |
| 100–150 | 19.5 | .85 | .77 | .31 |
| 150–200 | 12.5 | .92 | .88 | .20 |
| 200–240 | 9.5 | .89 | .84 | .16 |
| 240–300 | 7.0 | | .86 | .14 |
| Av. ratio | 1.0 | .89 | .81 | .25 |

(*a-2*) *Variation of Falling Rate Due to the Thickness of Mica Particles:* A preliminary test was made with a mica particle cut to about 2 millimeters square, having an original thickness of 2.3 millimeters and a settling rate of 235 millimeters per second. The cross-section was kept constant, but the thickness was reduced by splitting, and the settling rates were redetermined after measuring the thickness with a micrometer caliper. Curve *A* (Fig. 8) shows the relationship between the particle thickness and the rate of fall and indicates that a two-dimension measurement

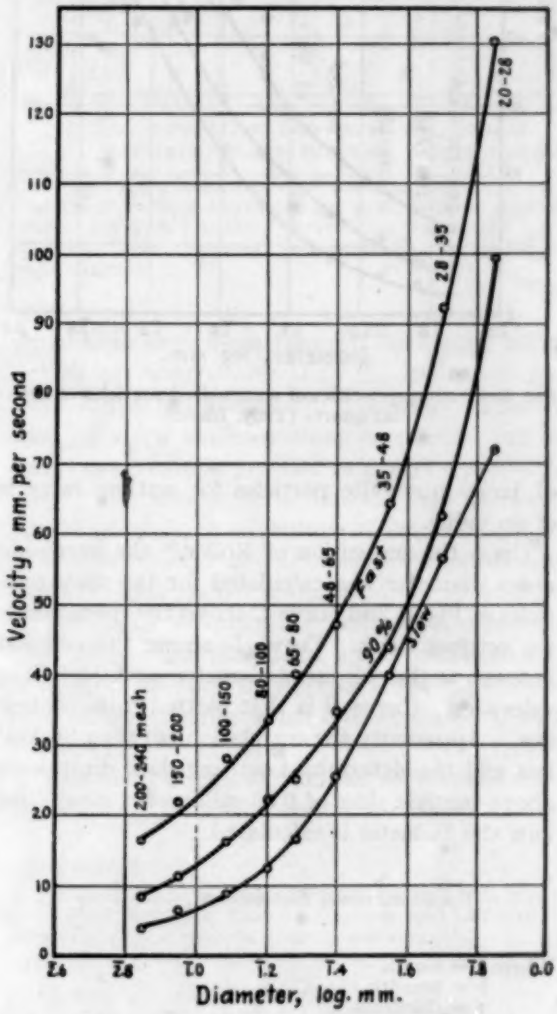


FIG. 4.—Falling velocities of screen-sized particles of subangular Belgian and New Jersey sands.

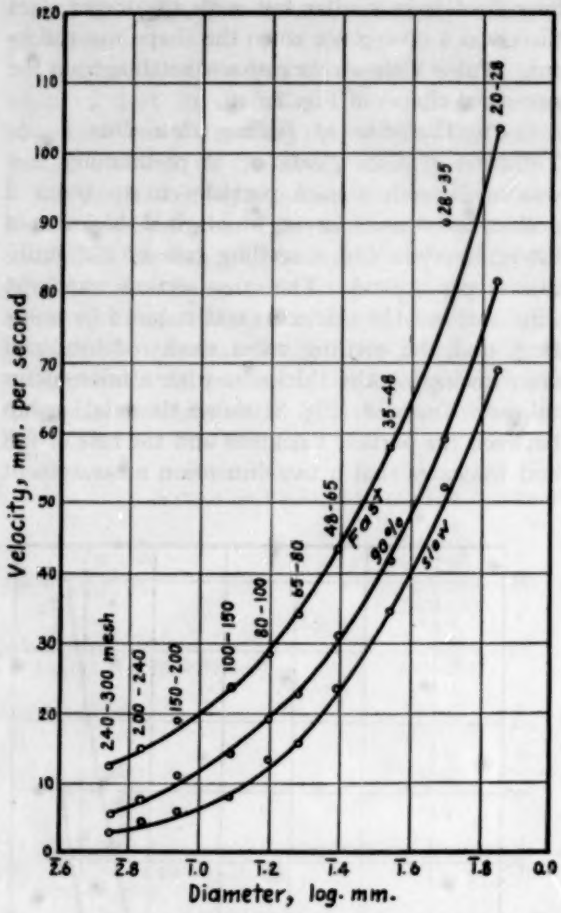


FIG. 5.—Falling velocities of screen-sized particles of angular quartz (Troy, Idaho).

of large muscovite particles for settling rates is of no value.

Upon the suggestion of Roller,[23] the harmonic mean diameter was calculated for the mica particles of Fig. 8, and curve *C* shows the corresponding settling rates. Curve *D* shows the relation between arithmetic mean diameters and the falling velocities. Curve *B* is that plotted from Stokes' law. Apparently the correlation between Stokes' law and the determined settling data disappears above particle sizes of 0.25 millimeter, no matter how the diameter is calculated.

$$\text{Harmonic mean diameter} = \frac{3lbt}{lb + li + bt}$$

Where $l$ = length.
$b$ = breadth.
$t$ = thickness.

[23] See p. 33 of footnote 14 (p. 130, this issue).

## IV. Falling Rate of the Finest Particles

The settling of the particles coarser than 240 mesh was observed by watching the particles during their fall and timing them with a stopwatch. A different method was necessary for the finer particles; 3-gram wetted samples settled through 1 meter of water at room temperature and the sediments collected on watch glasses were withdrawn from the bottom of the tube at intervals of 15, 30, and 45 minutes. The suspension remaining at the end was discarded, but the settled products obtained on the preliminary run were reclassified with fresh water. In the second classification, the first 15-minute product was sorted into 3-, 6-, 9-, 12-, 15-, and 18-minute sections. The 15- to 30-minute product was subdivided into 10-, 15-, 20-, 25-, 30-, 35-, and 40-minute sections. The 30- to 40-minute product was subdivided into 25-, 30-, 35-, 40-, 45-, 50-, and 55-minute sections. Microscope slides were made of the separates dispersed in glycerine. Images of the particles, magnified to an appropriate size up to 2300 diameters, were thrown from an arc-lighted microscope onto a ground glass in a dark room for sizing and counting. Five fields were counted on each slide.

The results were very irregular. Numerous fine particles were found with the coarse and a few coarse particles were found with the fine. A number of attempts was made to get better separations by de-airing the water and by settling in an alkaline medium.

### (1) De-Airing the Water

The presence of air in the water was thought to affect the settling rate of the particles. Air bubbles on the particles retard their fall and air

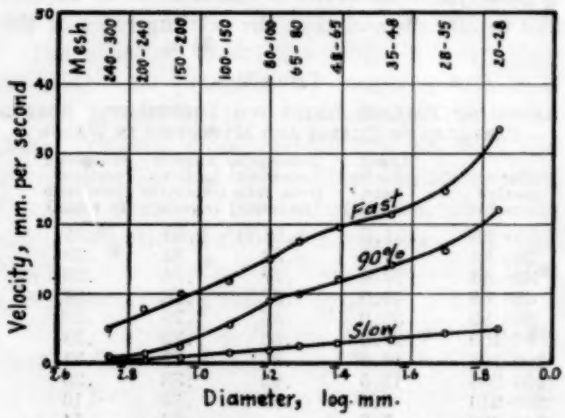


FIG. 6.—Falling velocities of screen-sized particles of muscovite mica.

bubbles rising through the water produce irregular settling. While considerable quantities of air were removed in a 15-minute treatment before each test by a vacuum siphon, the results for several series of tests were but slightly improved and showed a very imperfect classification.

### (2) Alkaline Suspension

Since a large portion of the settling troubles apparently was due to the coagulation of the sand and mica particles and the falling of aggregates at speeds corresponding to the diameters of the clusters, a better dispersion and separation were obtained by the addition of sodium silicate to produce a suspension having a $p_H$ of 10.5. Tests were made with quartz, mica, and kaolin particles with and without a de-aëration of this solution. The results indicated that the alkalinity was far more important than the de-aëration and the results for the subsieve sizes given in Fig. 1 were determined in alkaline solutions.

Mixtures of quartz, mica, and kaolin likewise were settled in alkaline suspensions, and clean separations were made between the kaolin, which settled at rates slower than 0.5 millimeter per second, and the fine quartz and mica. Alkali is used by a few kaolin-washing companies, but its use is not common practice in America and England. The present tests indicate that the addition of alkali is an advantage as far as the cleanness of separation is concerned. But most clay washers either do not understand the advantages of the alkali treatment or hesitate to add salts which may affect the plastic properties of the clay in the potteries and they prefer to waste a certain percentage of kaolin which falls and collects with the fine sand and mica.

Apparently Richards[24] did not use alkaline solutions for his study with quartz particles.

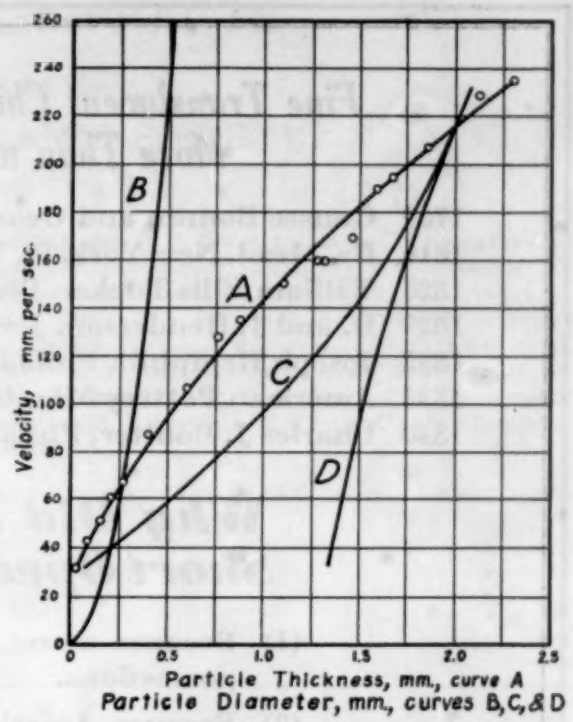


FIG. 8.—Falling velocities of a 2-mm. square muscovite particle of variable thickness, curve *A*; curve *B*, from Stokes' law with *k* as 960; curve *C*, settling rates for the harmonic mean diameter; and curve *D*, the arithmetic mean diameter.

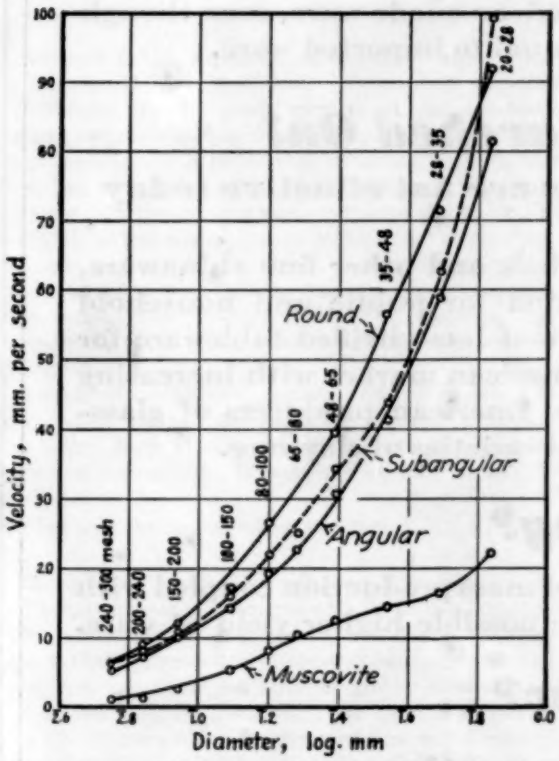


FIG. 7.—Comparative settling rates for round, subangular, and angular quartz and muscovite particles (90%).

#### Acknowledgment

Acknowledgment is made to Paul S. Roller for his review and suggestions, to R. Zane for drawings, and Kenneth G. Skinner for drawings and check calculations.

[24] See pp. 210–35 of footnote 21.

## *Fine Translucent China Made in America More Than a Century Ago*

**1769** Gousse Bonnin and George A. Morris, Philadelphia, Pa.
**1816** Dr. Mead, New York, N. Y.
**1825** William Ellis Tucker, Philadelphia, Pa.
**1829** D. and J. Henderson, Jersey City, N. J.
**1832** Joseph Hemphill, Philadelphia, Pa.
**1833** American Pottery Mfg. Co., Jersey City, N. J.
**1840** Charles J. Boulter, Philadelphia, Pa.

## *Why Did Each Have Short Operating Life?*

(1) Because secret formulas were sacred personal possessions.

(2) Because American housewives thought it not smart to use American-made ware, even though the quality was equal to imported ware.

## *Time Has Marched On!*

**These defeating causations are not effective today**

Lenox, Inc., producers of Belleek and other fine chinaware, several producers of vitrified china for public and household service, and many manufacturers of less vitrified tableware for decades have won and held the American market with increasing success and satisfaction, as have American producers of glassware, enamelware, and the several varieties of clayware.

## *Why?*

Because inventions of means of mass production coupled with better technical knowledge make possible higher yield of ware.

## *How?*

## *By Coöperation*

# CERAMIC ABSTRACTS

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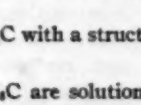
The bold-face number following the journal name is the volume; the issue number is in brackets, followed by the page numbers, then the year in parentheses.

April, 1937

16—4

## Abrasives

**Abrasion at high temperature.** Yoshiro Fujii. *Tetsu-to-Hagane*, **21**, 656–60 (1935); *Chem. Abs.*, **29**, 7898 (1935).—By use of a newly constructed abrasion tester various materials used in Diesel cylinder liners and piston rings were tested in lubricating oil at 200°. With cast iron, loss of weight reached 50 times that at room temperature. On two nitrided steels and seven C steels (0.1 to 0.9% C) the test was carried out under a load of 50 kg./sq. cm.; the best results were obtained with the two nitrided steels and 0.5 to 0.6% C steel. The loss of weight in these cases reached only $^1/_{10}$ to $^1/_{30}$ of that of the cast iron. The temperature of the cylinder wall was estimated to be lower that 200°.

**Borocarbide.** Adolph Voigt. *Oberflächentech.*, **13** [21] 245–46 (1936).—Borocarbide is made of boric acid and coke; both of these should be very pure and the boric acid dehydrated. It is formed at 2500 to 2600°C and has the formula $B_4C$ with a structure  . Compositions of $B_2C_2$ to $B_8C$ are solutions of the elements in $B_4C$ or mixtures of the elements with $B_4C$. It is considerably harder than silicon carbide and has a hardness close to that of diamond, greater compression strength and toughness, and an impact strength greater than that of the hardest tungsten carbides. The specific gravity is only 2.6. It has a high elasticity coefficient and a melting point of 2350 to 2500°C. The expansion coefficient is $4.5 \times 10^{-6}$ cm./°C, similar to Si carbide. The temperature coefficient of the electric resistance is negative and similar to that of carbon. Borocarbide is chemically resistant to the strongest alkalis and acids even at elevated temperatures and will stand 1000°C with excess of air where diamond begins to burn. It is used for grinding and polishing instead of diamond, but for these purposes it must be very pure and must not contain any graphite or metallic B. It is also used for orifices of sandblasting apparatus; the price is still very high. M.H.

**Grinding edges and surfaces of refractory brick.** E. Probst. *Schleif- & Poliertech.*, **13** [10] 223–29 (1936).—The best way to work refractory or acid-resisting material is to use special grinding machines. P. gives data on power and time required and descriptions and dimensions of grinding disks. Advantages of different machines are dealt with. Illustrated. F.E.V.

**Magnetite as a standard material for measuring grinding efficiency.** R. S. Dean. *Amer. Inst. Mining & Met. Engrs., Tech. Pub.*, No. 660, 5 pp. (Feb., 1936); *Metals & Alloys*, **7** [6] MA278 (1936).—Gross and Zimmerley (*Ceram. Abs.*, **10** [6] 448 (1931)) have proved that the energy actually used in grinding is proportional to the new surface produced. Gottschalk found that the coercive force of magnetite powder was directly proportional to surface area. To study crushing efficiency it is necessary only to charge the machine with 10-mesh magnetite and measure the power input while grinding. The coercive force of the ground sample is then determined by a simple method. Data are given to show that the method actually works.

**Method of comparing the hardness of electric-furnace products and natural abrasives.** Charles E. Wooddell. *Trans. Electrochem. Soc.* (Preprint), **68**, 18 pp. (1935); *Chem. Abs.*, **29** [22] 8265 (1935).—The relative resistances to abrasion during lapping are measured. The results

can be duplicated with a fair degree of accuracy. Considerable variation in hardness exists among diamonds. South American brown bort diamonds were found to be consistently harder than other types, although the South American ballas possessed a hardness which was almost identical with the bort. The carbonado diamond, which is usually considered the hardest of diamonds, was found to be considerably softer than the other varieties. The interval of hardness between corundum and the diamond is much greater than would be realized from a consideration of the Mohs' scale, and a comparative scale is given, extending from the diamond to quartz. The proposed scale based on the lapping method is as follows: bort 10, ballas 9.99, carbonado 9.82, boron carbide 9.32, black SiC 9.15, corundum 9.00.

BULLETIN

**Use of Abrasive Wheels.** ANON. *Brit. Home Office Safety Pamphlet*, No. 7, 52 pp. 5th ed. H. M. Stationery Office, London, 1936. Price 9d. The great increase in the use of abrasive wheels has made the dangers incidental to their use of increased importance, especially with regard to accidents and to dust inhalation. This book is a collaboration by manufacturers and Government inspectors. Illustrated. H.H.S.

PATENTS

**Abrading machine.** A. N. EMMONS (Porter-Cable Machine Co., Inc.). U. S. 2,069,700, Feb. 2, 1937 (June 22, 1934).

**Abrasive article.** BAKELITE, LTD. (Bakelite Corp.). Brit. 457,963, Dec. 23, 1936 (June 13, 1935).

**Abrasive article.** D. E. WEBSTER (Norton Co.). U. S. 2,070,764, Feb. 16, 1937 (Oct. 8, 1934). A grinding wheel comprises a substantially porous body of bonded abrasive grains having a central hole therethrough, a backing therefor composed of vulcanized hard rubber impregnating the surface pores of the abrasive body and forming an integral unit therewith which extends across the wheel hole and has a face engageable with a wheel support, a clamping plate remote from the face which is imbedded within the backing and located within the wheel hole to secure it against the wheel support, and means engageable with the plate for clamping the wheel assembly in position, whereby the backing distributes the clamping and driving forces between the wheel and its support.

**Abrasive wheel.** EDWARD VAN DER PYL (Norton Co.). U. S. 2,069,788, Feb. 9, 1937 (Aug. 7, 1935). The method of making a composite wheel comprises providing a thin metal disk, forming a groove in the periphery of the disk, providing an annulus of abrasive substance bonded with a suitable bond, the inside diameter of which is slightly greater than the diameter of the disk less twice the depth of the groove, opening the metal on either side of the groove, placing the disk in the annulus, and rolling or swagging the metal in place.

**Air-swept grinding mill.** CHRISTIAN NIELSEN (F. L. Smidth & Co.). U. S. 2,069,174, Jan. 26, 1937 (July 11, 1933).

**Apparatus for the manufacture of granule-coated webs.** W. J. TENNANT (Carborundum Co.). Brit. 457,462, Dec. 9, 1936 (May 27, 1935).

**Automatic grinding machine.** A. J. LEWIS (Baird Machine Co.). U. S. 2,070,283, Feb. 9, 1937 (Dec. 6, 1932).

**Automatic rouge feed for buffing machines.** R. S. SPERRY (Packer Machine Co.). U. S. 2,070,322, Feb. 9, 1937 (May 25, 1935).

**Beet knife sharpening machine.** S. T. FREAS AND N. C. BYE (Henry Disston & Sons, Inc.). U. S. 2,069,140, Jan. 26, 1937 (Feb. 14, 1934).

**Composite grinding wheel and method of making.** BAALIS SANFORD (Norton Co.). U. S. 2,069,116, Jan. 26, 1937 (Feb. 14, 1935). An abrasive wheel comprises a non-abrasive supporting disk formed of layers of fibrous sheets cemented together by a resinoid, and an annulus of abrasive grains and a resinoid bond peripherally surrounding and integral with the disk and forming a wheel body of substantially uniform thickness which has its two resinoid portions united by compression while plastic and set by heat as an infusible integral mass, wherein the fibrous sheets are arranged within the planes formed by the sides of the annulus and radially strengthen the wheel.

**Device to prevent buckling of sheet metal during grinding or polishing.** S. O. HANNA. U. S. 2,071,033, Feb. 16, 1937 (Aug. 15, 1936). U. S. 2,071,034, Feb. 16, 1937 (Aug. 15, 1935).

**Drill-grinding appliance.** G. D. HARDIN. U. S. 2,068,915, Jan. 26, 1937 (July 21, 1932).

**Gear-lapping machine.** E. W. MILLER (Fellows Gear Shaper Co.). U. S. 2,069,324, Feb. 2, 1937 (Feb. 26, 1934).

**Grinder.** J. J. WAAGE (Globe Slicing Machine Co., Inc.). U. S. 2,069,431, Feb. 2, 1937 (Feb. 17, 1932). The combination of a slicing machine having a rotary knife with a grinder support pivoted at a point spaced from the knife, a pair of grinders supported thereby and movable toward and away from the face of the knife.

**Grinding or abrading machines.** NORTON CO. Brit. 459,510, Jan. 20, 1937 (Sept. 19, 1934). F. WERNER A.-G. Brit. 459,551, Jan. 20, 1937 (June 17, 1935).

**Grinding device.** H. J. PERAZZOLI. U. S. 2,069,900, Feb. 9, 1937 (Oct. 25, 1934). A grinding device includes a pair of members mounted in spaced relation and having drum surfaces.

**Grinding machine.** W. G. BALDENHOFER (Thompson Grinder Co.). U. S. 2,068,529, Jan. 19, 1937 (March 28, 1932).

**Grinding machines for hard materials.** SPEED SURFACERS, LTD. Brit. 458,425, Dec. 31, 1936 (March 25, 1935).

**Grinding wheel.** NORTON GRINDING WHEEL CO., LTD. Brit. 459,470, Jan. 20, 1937 (April 18, 1935).

**Grinding wheel and method of balancing.** C. J. HUDSON (Norton Co.). U.S. 2,070,360, Feb. 9, 1937 (Dec. 9, 1936). The method of balancing an abrasive wheel consists in introducing into the pores of the wheel, on the light side of its axis, a sufficient quantity of pulverized mineral material in a vehicle of water with a wetting-out agent to make the weight of the light side substantially equal to the weight of the heavy side, the presence of such material not altering the grinding properties of the wheel.

**Honing tool.** K. W. CONNOR, G. M. CALVERT, AND ALBERT BLEASDALE (Micromatic Hone Corp.). U. S. 2,070,985, Feb. 16, 1937 (July 15, 1932).

**Knife grinder.** P. H. ROOT (Fate-Root-Heath Co.). U. S. 2,069,097, Jan. 26, 1937 (March 23, 1935).

**Lapping tools.** H. GORDON. Brit. 457,503, Dec. 9, 1936 (June 15, 1935).

**Lens grinding and polishing machine.** L. L. HOUCHIN. U. S. 2,070,733, Feb. 16, 1937 (June 12, 1936).

**Machines for grinding screw threads.** H. LINDNER. Brit. 458,991, Jan. 13, 1937 (June 8, 1935).

**Manufacture of bonded abrasive blocks, wheels, or disks.** W. J. TENNANT (Carborundum Co.). Brit. 457,463, Dec. 9, 1936 (May 27, 1935).

**Method and apparatus for the manufacture of granule-coated webs.** A. ABBEY (Carborundum Co.). Brit. 457,333, Dec. 9, 1936 (May 25, 1935).

**Method of forming diamondiferous abrasive compositions.** J. H. L. DE BATS (Howard W. Dix and Metal Carbides Corp.). U. S. 2,068,848, Jan. 26, 1937 (Feb. 23, 1934). The method of forming diamondiferous abrasive compositions comprises intimately admixing tungsten powder and carbon powder in amounts sufficient to form tungsten carbide, incorporating in the powdered mix up to $^1/_3$ of the mass of the same of particulate diamonds, tamping the diamondiferous mass in a carbonaceous crucible, heating the so-treated material to a temperature sufficient to cause coalescence and shrinkage of the mass, removing the crucible from the shrunken mass, heating the mass to a temperature sufficient to cause it to swell and assume a spongified, plastified condition while retaining its external solid aspect, removing the so-heated and spongified diamondiferous refractory mass to a drop-forge, and drop forging it at white heat with blows of the order of 5 to 250 tons and above.

**Method and means for polishing or surface-treating hollow ware, etc.** N. C. JOSEPH, LTD., AND B. C. JOSEPH. Brit. 459,244, Jan. 20, 1937 (Sept. 18, 1935).

**Process of manufacturing grinding tools.** PHILIPP VOEGELI-JAGGI. U. S. 2,070,734, Feb. 16, 1937 (May 15, 1934; Feb. 19, 1936). A grinding body comprises diamond particles, graphite, and ferric oxide bonded into a unitary mass by an artificial resin.

**Process for the preparation of grinding or polishing tools.** ERNST ELBEL AND OTTO SUSSENGUTH (Bakelite Corp.). U. S. 2,070,158, Feb. 9, 1937 (June 4, 1931). A process of preparing a moldable composition suitable for the manufacture of abrasive and polishing tools comprises bringing a member from the group consisting of urea-aldehyde and polybasic acid-polyhydric alcohol synthetic resins of the hardenable type into the *B*-state while in solution and mixing the solution obtained with abrasive.

**Production of abrasive grain and rubber mixes for the manufacture of bonded abrasive articles.** CARBORUNDUM CO. Brit. 460,226, Feb. 3, 1937 (Oct. 5, 1934).

**Reciprocating table drive mechanism for machine tools.** W. H. FEENEY (Brown & Sharpe Mfg. Co.). U. S. 2,069,138, Jan. 26, 1937 (June 19, 1935).

## Art and Archeology

**Ancient India in Indo-China.** H. G. QUARITCH WALES. *Discovery*, **17** [203] 335–38 (1936).—Discoveries of the first importance concerning ancient Indian settlements in Indo-China have been made this year by the Greater-India Research Expedition, of which W. is field director. An account of the work done at Takuapa and Sri Deva is presented and illustrated. H.H.S.

**Archeological native data from Santa Fé.** AMELIA LARGUIA DE CROUZEILLES. *Anales Soc. Cient. Argentina*, **122**, 326–34 (Dec., 1936).—Unearthed pieces of pottery from some river islands of northeastern Argentina, such as mouthless deity, duck's head, decorated vase, fragments of decorated black ware, and containers of peculiar design, are described and illustrated. T.W.GARVE

**Cerium oxide and a rare earth oxide in glazes.** B. W. MERWIN. *Jour. Amer. Ceram. Soc.*, **20** [3] 97–98 (1937).

**Color measurements.** J. L. MICHAELSON. *Jour. Amer. Ceram. Soc.*, **20** [3] 67–71 (1937).

**Early Chinese glass from pre-Han to T'ang times.** C. G. SELIGMAN, P. D. RITCHIE, AND H. C. BECK. *Nature*, **138** [3495] 721 (1936).—The authors made spectrographic analyses of 32 specimens of Chinese glass covering twelve centuries, pre-Han and Han (B.C. 250 or earlier to A.D. 220) and T'ang (A.D. 618 to 907). Of twenty-three specimens of pre-Han and Han glass, twenty were found to belong to the system PbO–BaO–$SiO_2$ with small amounts of soda, lime, etc. The lead was usually accompanied by tin and silver and often by traces of bismuth and antimony. Specific gravity ranged from 3.25 to 5.25. The other three Han glasses contained no barium. Of the nine T'ang glasses, seven were essentially soda-lime silicates and two were lead-soda-lime silicates. No barium was found, except for traces in 3 glasses. J.L.G.

**Harvard glass flower collection.** E. L. YORDAN. *N. Y. Times Mag.*, p. 23 (Feb. 7, 1937).—The Harvard collection includes more than 3500 glass models representing 832 species of flowers, plants, and shrubs, as well as enlarged analytical details. They are the work of Leopold and Rudolf Blaschka, Dresden; not only are they artistic masterpieces, but they evince microscopic fidelity to the natural world. M.V.C.

**Late 18th Century kiln-reject jars excavated at San Juan de Dios Hospital Foundation.** GENEROSO S. MACEDA. *Philippine Jour. Sci.*, **59** [4] 573–77 (1936).—Illustrated. F.R.R.

**Manufacture of porcelain of Tournai in the 18th Century.** H. NICAISE. *Verre & Silicates Ind.*, **7** [34] 404–407 (1936).—The history of the porcelain of Tournai was dominated by Peterinck, through whose genius, activity, business sense, and taste the porcelain industry flourished in 18th Century Belgium. The annexation to France dealt a fatal blow to his efforts and his porcelain became scattered. Decorations and motifs are described. See "Hard—" *Ceram. Abs.*, **15** [9] 279 (1936). M.V.C.

**Methods of determining gloss.** RICHARD S. HUNTER. *Jour. Research Nat. Bur. Standards*, **18** [1] 19–39 (1937); R.P. 958. Price 5¢.—Glossiness is evidenced by almost every object and is to be attributed to specular reflection. Specular reflection occurs at the surfaces of reflecting objects, and, because of the diversities of minute surface structure, many kinds of glossy appearances result. An attempt to classify these glossy appearances has led

to the description of six kinds of gloss: (1) specular gloss, identified by shininess; (2) sheen, identified by surface shininess at grazing angles; (3) contrast gloss, identified by contrasts between specularly reflecting areas of surfaces and other areas; (4) absence of bloom gloss, identified by the absence of reflection haze or smear adjacent to reflected high lights; (5) distinctness-of-reflected-image gloss, identified by the distinctness of images reflected in surfaces; and (6) absence-of-surface-texture gloss, identified by the lack of surface texture and surface blemishes. Data which describe the directional distribution of light reflected by surfaces illuminated under specified conditions furnish the fundamental physical basis for describing gloss. Such distribution data, however, are cumbersome and involved and include the effects of both diffuse and specular reflection. H. suggests that the designer of a gloss meter should determine from goniophotometric data taken on representative samples what differences in apparent reflectance are most characteristic of the differences in glossiness observed visually. Descriptions of typical gloss instruments and of measurements made by them and a bibliography on gloss are included. Differences between the various types of gloss are analyzed in detail.

R.A.H.

**Poetic pottery.** R. B. Hepple. *Notes & Queries*, **171**, 119–20 (1936).—Pottery bearing verse, alone or accompanied by decoration in the way of scenery, is described.

H.H.S.

**Pottery making in Fiji.** K. Roth. *Jour. Roy. Anthrop. Inst.*, **65**, 217–34 (1935).—A complete and excellently photographed account of a craft which is rapidly disappearing is given.

H.H.S.

**Roman tile kiln in England.** S. E. Winbolt. *Discovery*, **17** [201] 282–84 (1936).—A Roman tile (*tegula*) factory has been excavated at Ewhurst, Surrey. Photographs and a plan of the kiln are given.

H.H.S.

**Sidelights on the history of ceramics.** L. Conton. *Corriere Ceram.*, **17** [11] 321–23 (1936).—In the study of 16th Century manufacture of ceramic ware, the Potter's Art by Piccolpasso (*Ceram. Abs.*, **13** [9] 230 (1934)) is authoritative and is referred to often. C. quotes passages from the works of little-known contemporaries of Piccolpasso, Leonardo Fioravanti and Tomaso Garzoni, who, although their methods were primitive and crude, were none the less interesting in that they were among the first teachers.

M.V.C.

**Tin glazes.** J. Liebscher. *Zprávy Československ. Keram. Společnosti*, **11**, 65–69 (1934); abstracted in *Chem. Zentr.*, **1935**, ii, 2863.—The so-called "fused glazes," used in Europe before the discovery of porcelain, contained $SnO_2$ as opacifier and white pigment. Batches for white, blue-green, blue, green, and brown glazes are analyzed, and the effect of some additions such as minium, $B_2O_3$, $K_2CO_3$, NaCl, and soda, as well as the production of opaque glazes, is discussed.

M.V.C.

BOOK

**Exhibition of English Pottery, Old and New.** Anon. H. M. Stationery Office, London, 1936. 64 pp. Price 2s. This book of photographs makes possible a comparison of contemporary and traditional styles in the potter's craft. It is so arranged that pictures of early English and some Chinese, Japanese, and Korean ware are contrasted with products of living artists. The book is from the Victoria and Albert Museum, London.

H.H.S.

PATENTS

**Apparatus for printing on glass, etc.** C. G. Anderson. U. S. 2,068,649, Jan. 26, 1937 (Dec. 21, 1933). A printing plate for printing upon glass comprises an integral metallic sheet of uniform thickness with a flat face having means for printing a design.

**Designs for:**

**Ashtray.** W. E. Mackelfresh, Jr. (Owens-Illinois Glass Co.). U. S. 103,115, Feb. 9, 1937 (April 29, 1936).

**Bottle.** E. W. Fuerst (Owens-Illinois Glass Co.), U. S. 102,822 and 102,823, Jan. 19, 1937 (July 22, 1936). J. H. Funkey (Carr-Lowrey Glass Co.), U. S. 102,859, Jan. 19, 1937 (Dec. 2, 1936). W. R. Kohl (Carr-Lowrey Glass Co.), U. S. 103,156 to 103,158, Feb. 9, 1937 (Dec. 4, 1936). A. I. Lorenzen (Owens-Illinois Glass Co.), U. S. 102,910, Jan. 26, 1937 (March 20, 1936).

**Bowl.** Findley Williams (Fostoria Glass Co.). U. S. 102,772, Jan. 19, 1937 (Nov. 11, 1936).

**Butter tub.** Yukio Buma (Morimura Bros., Inc.). U. S. 103,032, Feb. 2, 1937 (Dec. 10, 1936).

**Combined place-card holder, nut dish, and ash tray.** E. M. Bottome (Fostoria Glass Co.). U. S. 102,743, Jan. 19, 1937 (Nov. 17, 1936).

**Covered dish.** Anne Swainson (Montgomery Ward & Co., Inc.). U. S. 103,169, Feb. 9, 1937 (June 29, 1936).

**Creamer.** Yukio Buma (Morimura Bros., Inc.). U. S. 103,028, Feb. 2, 1937 (Dec. 10, 1936).

**Cup.** Anne Swainson (Montgomery Ward & Co., Inc.). U. S. 103,168, Feb. 9, 1937 (June 29, 1936).

**Glass.** E. W. Fuerst (Libbey Glass Co.). U. S. 103,148, Feb. 9, 1937 (Dec. 10, 1936).

**Goblet.** E. M. Bottome (Fostoria Glass Co.). U. S. 102,744, Jan. 19, 1937 (Nov. 17, 1936). A. J. Cunningham. U. S. 102,816 to 102,818, Jan. 19, 1937 (June 9, 1936). U. S. 103,277, Feb. 16, 1937 (Dec. 23, 1936).

**Jam jar.** Yukio Buma (Morimura Bros., Inc.). U. S. 103,031, Feb. 2, 1937 (Dec. 10, 1936).

**Kettle.** A. W. Nelson (Columbian Enameling & Stamping Co.). U. S. 102,953, Jan. 26, 1937 (May 18, 1936).

**Lavatory unit.** W. W. Krolop. U. S. 103,111, Feb. 9, 1937 (Nov. 23, 1936).

**Pitcher.** Anne Swainson (Montgomery Ward & Co., Inc.). U. S. 103,167, Feb. 9, 1937 (June 29, 1936).

**Plate.** H. E. Barth (New Martinsville Glass Mfg. Co.), U. S. 102,812, Jan. 19, 1937 (Dec. 7, 1936). E. M. Bottome (Fostoria Glass Co.), U. S. 102,742, Jan. 19, 1937 (Nov. 17, 1936). Yukio Buma (Morimura Bros., Inc.), U. S. 102,778, Jan. 19, 1937 (Oct. 16, 1935). U. S. 103,004 to 103,009 and U. S. 103,034 to 103,042, Feb. 2, 1937 (Dec. 10, 1936). G. J. Higginson (Johnson Bros. (Hanley), Ltd.), U. S. 103,232, Feb. 16, 1937 (Jan. 2, 1937). C. L. Sebring (Sebring Pottery Co.), U. S. 102,862, Jan. 19, 1937 (April 25, 1936). Annie Trarieux (Onondaga Pottery Co.), U. S. 103,256 and 103,257, Feb. 16, 1937 (July 18, 1936).

**Platter.** ANNE SWAINSON (Montgomery Ward & Co., Inc.). U. S. 103,166, Feb. 9, 1937 (June 29, 1936).

**Salt and pepper shaker.** YUKIO BUMA (Morimura Bros., Inc.). U. S. 103,033, Feb. 2, 1937 (Dec. 10, 1936).

**Saucepan.** A. W. NELSON (Columbian Enameling & Stamping Co.). U. S. 102,954, Jan. 26, 1937 (May 18, 1936).

**Sugar bowl.** YUKIO BUMA (Morimura Bros., Inc.). U. S. 103,029, Feb. 2, 1937 (Dec. 10, 1936).

**Teapot.** YUKIO BUMA (Morimura Bros., Inc.). U. S. 103,030, Feb. 2, 1937 (Dec. 10, 1936).

## Cements

**Annular deposit in cement rotary kilns.** T. YOSHII. *Zement*, 25 [42] 727–32 (1936).—Y. discusses the following causes of ring formation: coal and ash, kiln construction, refractory lining, kiln regulation, and clayey materials. Tests have proved that raw materials rich in silica and poor in lime show little tendency toward ring formation. Y. computes a special lime-silica modulus which should be lower than 3.19: total lime minus lime in aluminate, divided by silica (in molecular equivalents) < 3.19. The usual methods of destroying annular deposits are criticized and some improvements are suggested. F.E.V.

**Crystal structure and chemistry of cement.** E. BRANDENBERGER. *Archiv. Angew. Wissenschaft & Technik*, 2 [2] 45–48 (1936); abstracted in *Referat. Silikatliteratur*, 3 [11] 3406 (1936).—The crystal structure of silicates is studied. The poor crystal formation of cement chemical compounds complicates the determination of their crystal structure and, consequently, the explanation of their constitution. From the results of the study of the crystal structure of silicates, however, B. makes predictions on Ca silicates. Some results of Röntgenographic studies of the hardening process are discussed. M.V.C.

**Determination of rational composition of Portland cement.** V. DI S. SARDOFONTANA. *Cemento*, 6, 295–96 (1934); *Chem. Zentr.*, 1935, i, 612–13; *Brit. Chem. Abs.-B*, 54 [31] 675 (1935).—A method of calculating the composition in terms of $2MgO \cdot SiO_2$, $2CaO \cdot Fe_2O_3$, $2CaO \cdot Al_2O_3$, $2CaO \cdot SiO_2$, and $3CaO \cdot SiO_2$ is described.

**Development in the manufacture of special Portland cements.** HESS. *Zement*, 25 [44] 757–60 (1936).—In the last two years, many species of Portland cements have been commended, each with one special property, *e.g.*, high initial strength, high elasticity, high plasticity, wear resistance, corrosion resistivity, etc. This specialization is excessive. H. considers four clinker minerals, *viz.*, $3CaO \cdot SiO_2$, $2CaO \cdot SiO_2$, $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$, and $3CaO \cdot Al_2O_3$ and describes their essential properties. He considers the possibility of increasing three desired properties of cements: (1) high initial strength due to large percentage of alite; (2) small hydration heat due to high content of dicalcium silicate which ensures slow and steady increase of strength; and (3) small shrinkage and good resistivity in the presence of aggressive solutions due to the elimination of lime aluminates. The determination of clinker minerals is essential to foresee the behavior of special cements. The content of alumina being low, the computation from analysis is satisfactory. F.E.V.

**Development of street cements.** H. E. SCHWIETE. *Zement*, 25 [46] 791–98 (1936).—By changing clinker mineral composition, it is possible to develop better properties for street construction. Improvement depends essentially on tricalcium silicate contents. Milling fineness is an important factor. The shrinkage and the elastic behavior are improved by rough milling, *i.e.*, reduction of active surface. The best fineness is determined by the moderate decrease of strength and workability. Some tests made by S. with special cements showed their inferiority in comparison with standard cements. F.E.V.

**Hydrates of calcium ferrites.** H. HOFFMANN. *Zement*, 25 [8] 113–17; [9] 130–32; [39] 675–80; [40] 693–98; [41] 711–16 (1936).—Up to now, calcium ferrites contained in Portland clinker have not received the attention which they deserve. Researches were made by H. to determine hydrated combinations between $Fe(OH)_3$ and $Ca(OH)_2$ and to ascertain if anhydrous calcium ferrites in the presence of water give such hydrates. The formation of unstable or gel-like products did not allow the determination of all the interesting properties. Results are summarized as follows: (1) Chemical and X-ray investigations have shown the formation of two salts, $4CaO \cdot Fe_2O_3 \cdot nH_2O$. (2) These salts differ in structure and water content (14 and $7H_2O$). (3) Hydration of $2CaO \cdot Fe_2O_3$ and $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ gives two different calcium ferrite hydrates, both of white color; their stability depends on lime concentration in water. (4) Above 1060 mg. CaO/liter, the stable hydrate is $4CaO \cdot Fe_2O_3 \cdot nH_2O$. (5) The same hydrate is a transient apparition if lime concentration is lower. (6) Between 1060 and 640 mg. CaO/liter, another hydrate is stable; its formula could not be determined. (7) Below 640 mg. CaO/liter, no hydrate is in equilibrium with the solution; hydrolysis gives free $Fe(OH)_3$. (8) Normal hydration of $2CaO \cdot Fe_2O_3$ creates 1060 mg. concentration; the two hydrates are formed. (9) Hydration of $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ creates 640 mg. concentration; low lime ferrite hydrate, $Fe(OH)_3$, and $3CaO \cdot Al_2O_3 \cdot nH_2O$ are formed. (10) $CaO \cdot Fe_2O_3$ does not react with water or limewater. See *Ceram. Abs.*, 15 [5] 143 (1936). F.E.V.

**Inorganic cement and adhesive.** DEAN S. HUBBELL. *Ind. Eng. Chem.*, 29 [2] 123–32 (1937).—The shortcomings which have restricted the use of magnesium oxychloride cements are eliminated by the additon of 10% of finely divided copper powder. During the hardening of the cement and for long periods following, the metal is converted to a new cementing material that resembles the natural mineral, atacamite. The formation of this new phase in the cement composition increases its strength and resistance to abrasion, prevents its damage by water, eliminates harmful expansion, reduces efflorescence, and imparts sufficient tolerance of lime to permit of permanent bond to Portland cements. The new compositions have an unusual combination of properties which fits them for wide utility. Illustrated. F.G.H.

**Magnesia content of Portland cement: I.** Y. SANADA AND G. NISHI. *Jour. Soc. Chem. Ind. Japan*, 39 [11] 400B (1936).—The Japanese specification for the limit of the magnesia content in Portland cement is 3%, although

the authors in previous tests found that 12% can be safely used. In the preparation of magnesium ferrite, $MgO \cdot Fe_2O_3$, the authors ascertained that (1) it is obtained at 1350°C; (2) it is insoluble while the free MgO is soluble in 0.5 *N* acetic acid; and (3) the MgO remaining after the formation of $MgO \cdot Fe_2O_3$ exists as free MgO in the clinker of $MgO \cdot Fe_2O_3$. For Part II see *Ceram. Abs.*, **14** [9] 209 (1935). M.V.C.

**Properties of cements rich in magnesia.** H. Schwiete and H. zur Strassen. *Zement*, **25** [49] 843–46; [50] 861–65, 879–82 (1936).—According to recent research, it is possible to allow, under certain conditions, a high percentage of MgO without affecting the volume permanency. The conditions of equilibrium of CaO, MgO, $Al_2O_3$, $Fe_2O_3$, and $SiO_2$ determine the concentrations which ensure chemical binding of MgO by the acidic reagents. This is possible only when the lime content is too low to saturate the reagents. The formation of tricalcium silicate takes place only when $Al_2O_3$ and $Fe_2O_3$ are saturated with lime. In the presence of tricalcium silicate, magnesia is in the free state (periclase); $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ is able to incorporate as a mix crystal 2% of its weight of CaO. Calculated on the total clinker, this amounts to 0.2 to 0.3% as bound MgO. The green color of clinker is due to these mix crystals. The method of computing mineral composition of the clinker is as follows: $2CaO \cdot SiO_2$, $4CaO \cdot Al_2O_3 \cdot Fe_2O_3$, $3CaO \cdot Al_2O_3$ (if excess of alumina), $2CaO \cdot Fe_2O_3$ (if excess of iron oxide), $3CaO \cdot SiO_2$; MgO is then free. In one instance, a shortage of lime controlled the absence of tricalcium silicate and the formation of spinel in the presence of excess free magnesia. The chemical and quantitative X-ray analysis verified the previsions. During firing, magnesia intervenes in transient compounds such as $3CaO \cdot MgO \cdot 2SiO_2$ (merwinite) and $MgO \cdot (Al, Fe)_2O_3$ (spinel), but in standard concentrations these compounds have no importance. The Balthasar process allows a high content of magnesia (greater than 5%), but the volume permanency remains questionable. F.E.V.

**Thermodynamics of cements.** H. E. v. Gronow and O. Honus. *Zement*, **25** [47] 812–14 (1936).—Some rectifications of heats are given. $Ca + 0.5O_2 = CaO + 150 \pm 2$ K/mol.; $Ca + Si + 1.5O_2 = CaO \cdot SiO_2 + 353.4$ K; $Ca + 2Fe + 2O_2 = CaO \cdot Fe_2O_3 + 365.0$ K; and $Ca + 2Al + 2O_2 = CaO \cdot Al_2O_3 + 547.8$ K. The transformation of water-free kaolinite in free oxides liberates $15 \pm 1$ K at 950°C, the change from $\gamma$- to $\alpha$-alumina being already included. F.E.V.

**Zinc phosphate cement.** R. H. Volland, George W. Paffenbarger, and W. T. Sweeney. *Jour. Amer. Dental Assn.*, **22**, 1281–1306 (1935); *Chem. Abs.*, **29**, 7525 (1935).—The cement powder is essentially calcined ZnO modified with MgO and other oxides. The liquid is an aqueous solution of $H_3PO_4$ buffered by the addition of ZnO, $Al(OH)_3$, or both. The setting time depends on such factors as degree of calcination of the powder, $H_2O$ content of the liquid, mixing technique, proportion of powder and liquid, temperature of mixing slab, and time of mixing.

BULLETIN

**Conditions for the formation of hydrated compounds in system $CaO–Al_2O_3–H_2O$ (liquid) and the hydration of anhydrous calcium aluminate.** Gunnar Assarson. *Sveriges Geol. Undersökning.*, Series C, Arsbok 30, No. 399, 190 pp. (1936); abstracted in *Chem. Zentr.*, **1936**, ii, 3934–35.—The following components present in the $CaO–Al_2O_3–H_2O$ system were determined and their mineralogical and optical properties ascertained: $Ca(OH)_2$, $5CaO \cdot Al_2O_3 \cdot 34H_2O$, alpha-$4CaO \cdot Al_2O_3 \cdot 14H_2O$, alpha-$4CaO \cdot Al_2O_3 \cdot 12H_2O$, beta-$4CaO \cdot Al_2O_3 \cdot 14H_2O$, $3CaO \cdot Al_2O_3 \cdot 6H_2O$, $3CaO \cdot Al_2O_3 \cdot 12H_2O$, $2CaO \cdot Al_2O_3 \cdot 9H_2O$, $CaO \cdot Al_2O_3 \cdot 10H_2O$, and $Al(OH)_3$. See *Ceram. Abs.*, **15** [3] 82 (1936). M.V.C.

## Enamel

**Acidproof enameling on cast iron.** P. C. Stone. *Foundry Trade Jour.*, **54** [1029] 366–68 (1936).—Acidproof finish on sheet metal can be easily secured because the stock, or metal, is produced free from impurities. The same condition of purity can not be claimed for cast iron, particularly as far as the surface of the metal is concerned. For good acidproof enameling of cast iron, the castings must be clean, even in thickness, free from burned-in sand and heavy lugs (unless cored), thoroughly annealed, and properly blasted. Much is needed in design in sheet-metal parts, especially in castings. Cleanliness is stressed, and daily coöperation between the enameler and the foundry will be an enormous contribution toward success. As leadless enamels superseded those containing lead, so must acidproof enamels replace others. H.E.S.

**Adherence of enamel to metals.** J. Roudnik and A. Litvin. *Congr. Chim. Ind., 15th Congress, Brussels*, **2**, 616–27 (1935); abstracted in *Chem. Zentr.*, **1936**, ii, 3714.—After a comprehensive discussion of theories dealing with the adherence of enamel, the authors give results related chiefly to the effect, on adherence, of metallic oxides, oxide adhering layers, and various furnace atmospheres during the firing of enamel. Enamel adherence was determined by bending and impact strength experiments. It was found that oxygen does not play such an important rôle in the adherence of enamel as heretofore assumed, while the nature of the surface and its structure, as well as the composition of the ground material, have a decisive effect on the adherence of enamel. The surface stresses are of secondary importance. M.V.C.

**Adhesion of enamel to steel produced by the electrodeposition of $Mo(OH)_3$ on the steel.** C. R. Amberg, H. D. Prior, and J. C. Richmond. *Jour. Amer. Ceram. Soc.*, **20** [3] 75–77 (1937).

**Decorations and special finishing methods.** Anon. *Better Enameling*, **7** [7] 23–24 (1936).—Among decoration and special finishing processes used in the porcelain enamel industry are the use of decalcomania, printing, and the screen-process method; all are described in detail. Stippling is also taken up. E.J.V.

**Effect of soluble salts formed during aging on the scumming of enamels.** R. J. Whitesell. *Jour. Amer. Ceram. Soc.*, **20** [3] 72–75 (1937).

**Enamel mill-room practice.** G. Steele. *Foundry Trade Jour.*, **54** [1029] 369–72 (1936).—The ease with which the enamel may be applied and handled and the

quality of the finished enamel product are, to a large extent, dependent on the development and maintenance of a satisfactory mill-room technique. The best conditions for wet-grinding efficiency are as follows: (1) The charge of grinding media must be of as small a size as practicable (75 to 90%) with a few larger sizes (10 to 25%) to act as agitators and crushers of the larger pieces of frit. (2) The charge should be 45% of the volume of the mill. (3) The speed of rotation should be such that the charge remains compact but rises to the maximum height on rotation, maintaining the pebbles in this compact form. (4) The frit must constitute 21.5% of the volume of the mill. (5) The water should constitute 8.5% of the volume of the mill. H.E.S.

**Enameling industry and the Institute of Vitreous Enamelers.** W. H. WHITTLE. *Foundry Trade Jour.*, **54** [1012] 22 (1936).—A brief review of the activities and meetings of the Inst. of Vitreous Enamelers during 1935 is given. H.E.S.

**Enameling iron: its behavior in enameling.** KARL KAUTZ. *Metals & Alloys*, **5**, 167–69 (1934); *Chem. Abs.*, **28** [20] 6541 (1934).

**Firing sheet-steel enamel.** ANON. *Better Enameling*, **7** [5] 21–22 (1936).—Because of the light weight of metal that must be heated to the proper temperature for fusing enamel, a short sharp heat is used for sheet-metal enameling. Sheet-steel enamel is dried as soon as possible after application of the enamel. Brushing is carried out immediately after the finish coat is dried. The firing temperature ranges from 1450 to 1550°; for the usual type of work, gage of metal, design of ware, and kind of enamel influence the firing temperature. The equipment required and routine followed are described. Illustrated. E.J.V.

**Firing wet-process cast-iron enamel.** ANON. *Better Enameling*, **7** [4] 17–20 (1936).—All wet-process cast-iron enamel must be thoroughly dried before firing. In continuous equipment, a drier in the form of a preheating chamber precedes the furnace. Because of the time required to fuse porcelain enamel to cast iron, owing to the weight of metal that must be heated before fusing takes place, a lower firing temperature is used and multiple decking of cast-iron ware is resorted to in order to increase the production of finished ware. The equipment necessary for firing wet-process cast-iron enamel is listed, and the routine followed is described. Illustrated. E.J.V.

**Handling small parts in large quantities.** R. L. FELLOWS AND H. D. CHASE. *Better Enameling*, **7** [6] 8–11 (1936).—The authors give a detailed description of the plant, equipment, and methods used at the D. L. Auld Co., Columbus, Ohio, makers of small commercial products such as name plates for refrigerators and other household equipment, automobile hub caps, radiator emblems, etc., in porcelain enamel. Illustrated. E.J.V.

**Influence of molding material on surface and structure of cast iron.** D. DIOSZEGHY. *Magyar Kir. József Nádor Müszaki Gazdasagtudományi Egyetem Bánya-, Kohó-, Erdömérnöki Kar, Sopron. A bánya kohómérnöki osztály Kozleményei*, **8**, 301–10 (1936).—Several native (Hungarian) molding sands were examined with regard to (1) behavior of the pure sand during casting, (2) effect of the coal dust, and (3) microstructure of the cast iron as affected by the molding material. As the molten Fe exerts on the sand not only a thermal but also a chemical effect, the refractoriness of the sand is not fully determined by Seger cones; casting tests should be made. Sticking (fritting-on) of the sand to the casting with sands containing more than 15% lime could be prevented by addition of $CaCO_3$ which decomposes and gives a clean surface on account of the $CO_2$ pressure developed in the decomposition. The coal dust forms a gas layer around the sand grains; the best effect was obtained with 8% addition of dust of less than 0.06 mm. grain size and 6% water. The S content had no harmful effect. If the cast Fe contains much C + Si, the cooling rates, which differ with the type of sand, affect the microstructure of the casting. The outer zone of the casting, when cast in molds with much lime, was richer in pearlite than that of a casting cast in sand with poor lime content but containing coal dust. As it is this pearlitic zone of the castings which has good wear resistance, a clean surface is of importance (cleaning, which reduces its thickness, is not necessary). M.H.

**Inspection and shipping.** ANON. *Better Enameling*, **7** [8] 23–24 (1936).—Inspection of completely finished porcelain enameled ware is discussed; the checking operations depend on the type of ware being made. The shipping of porcelain enameled ware requires precautions to reduce the amount of damaged ware. Methods of wrapping and crating porcelain ware are described. E.J.V.

**Modern tendencies in vitreous enameling.** H. HALLSWORTH. *Sheet Metal Ind.*, **10** [115] 869–78 (1936).—H. surveys modern developments in the vitreous enameling industry during the past 10 years under five main headings: (1) the enamel itself, (2) preparation of the metal prior to enameling, (3) application of the enamel and drying of the enameled ware, (4) furnaces and equipment, and (5) control. A.P.S.

**Old company with young ideas.** H. D. CHASE AND E. W. GOETZ. *Better Enameling*, **7** [4] 14–16 (1936).—A historical sketch of the Seeger Refrigerator Co., from its start in 1906 to the present-day modernized plant, is given. Illustrated. See *Ceram. Abs.*, **15** [9] 270 (1936). E.J.V.

**Porcelain enamel is standard for California road signs.** E. GIDLOW. *Better Enameling*, **7** [7] 12–14 (1936).—G. gives the history of the use of porcelain enamel road signs in Calif., showing standardization, economy of expenditure through volume buying, and centralized planning. Porcelain enamel signs were first used in 1911. E.J.V.

**Preparation of iron castings for vitreous enameling by sandblasting.** F. W. WILSON. *Foundry Trade Jour.*, **54** [1011] 7–10 (1936).—The preparation of iron castings for vitreous enameling by sandblasting is considered under the following headings: (1) types of plant used, (2) abrasives, (3) air pressures, (4) nozzles, and (5) operating troubles. A discussion is included. H.E.S.

**Substitution of enameled iron vessels for glass beakers.** P. S. KLUNNE. *Chem. Weekblad*, **31**, 366–67 (1934); *Brit. Chem. Abs.-B*, **54** [27] 591 (1935).—Enameled Fe vessels have given satisfactory service for $1^1/_2$ years when used at temperatures between −10° and 300°. Flaking of the enamel does not occur if the film is sufficiently thin.

**Use of the interferometer in the porcelain enameling industry.** E. E. HOWE AND L. A. LANGE. *Better Enameling*, **7** [9] 11–13 (1936).—The most accurate and reliable means of determining the thermal expansion characteris-

tics of an enamel is through the use of the interferometer which utilizes the interference method whereby monochromatic light is transmitted, reflected, and refracted in such a way as to detect very small changes in length of an enamel specimen upon heating. A detailed discussion of the theory and operation of the interferometer is presented. Illustrated. E.J.V.

**Wood graining and marbleizing.** ANON. *Better Enameling*, **7** [6] 22–24 (1936).—Wood graining for the decoration of porcelain enameled ware has been in use for a number of years. Two methods used are the Grand Rapids method, comparable to printing in that it consists of the direct application of a design from a curved plate to the surface being enameled, and a method comparable to off-set printing in that it is indirect rather than direct from the printing plate. Marbleizing is also done by direct and indirect methods. These are described in detail, the necessary equipment being listed. Illustrated. E.J.V.

**Use of the microscope in the porcelain enameling industry.** E. E. HOWE. *Better Enameling*, **7** [6] 13–16; [7] 20–22 (1936).—H. points out the adaptability of the microscope for studying some of the problems concerning porcelain enameling which could not be studied by other methods. He takes up methods of illuminating the sample under the microscope, preparation of the sample, metallography of sheet iron and cast iron, and photomicrographs of enamels in sections through the enamel and metal. The use of the petrographic microscope in the study of raw materials is also discussed. E.J.V.

BOOKLET

**Porcelain enameling.** ANON. *Chicago Vitreous Enamel Product Co. Booklet*, 16 pp.; reviewed in *Ceram. Age*, **27** [6] 178 (1936).—Several articles on porcelain enameling are reprinted. F.G.H.

PATENTS

**Enameled product and method of making.** O. E. HARDER AND J. D. SULLIVAN (Battelle Memorial Institute). U. S. 2,070,272, Feb. 9, 1937 (Aug. 8, 1934). The method of producing a vitreous enameled product comprises applying vitreous enamel on a precipitation-hardening alloy, heating such enamel to effect fusion thereof, and then subjecting the enameled article to a temperature within the precipitation-hardening range for a period of time adequate to effect hardening of the alloy by precipitation.

**Furnace.** E. W. DANY (Ferro Enamel Corp.). U. S. 2,069,057, Jan. 26, 1937 (April 6, 1935).

**Method for enameling tanks.** W. G. MARTIN (A. O. Smith Corp.). U. S. 2,070,368, Feb. 9, 1937 (June 8, 1935). In the fusing of a vitreous enamel lining to the interior of the tank, the step which comprises replacing air within the tank with another atmosphere by introducing solid particles of the other atmosphere into the tank and thereafter vaporizing them to form a gas.

## Glass

**Alloy steels as material for glass molds.** O. HENGSTENBERG, H. MÜLLER, AND F. STÄBLEIN. *Fachausschussber.* (Deut. Glastech. Ges.), No. 31, pp. 135–39 (1934); *Chimie & Industrie*, **33**, 876 (1934); *Chem. Abs.*, **29**, 4909 (1935).—C steels, Cr steels, and Ni-Cr steels (with additions of Mo, Si, or Al in certain cases) were tried. The important points to consider are oxidation at working temperature (which governs the time of persistence of polish) and adhesion of the glass to the metal. Relative oxidation below 600° was found to be similar to that above 600°. For a glass of given composition, the temperature at which adhesion to the metal takes place varies but little with different metals but depends to a considerable extent on the composition of the glass. When a cast Fe mold is replaced by an alloy steel mold, the mean temperature must be kept lower on account of the lower heat conductivity.

**Applications of nickel alloys in the glass industry.** ANON. *Nickel Bull.*, **9** [11] 229–33 (1936).—Equipment used in the melting process, glass manipulation, molding and annealing, thermocouple wire and electric heating elements, glass pickling with HF, and acetate handling are best served by Ni, Ni-Cr, or Ni-Cr-Fe alloys. H.H.S.

**Bubbles during fusion of the frit.** ANON. *Sprechsaal*, **69** [20] 285 (1936).—Besides the familiar bubbles formed on the surface of the melt, large bubbles form in the frit and occasionally rise; their cause and the danger from them are discussed. M.V.C.

**Chrome-plated molds for semiautomatic machines of the Kutcher type.** V. I. PANASYUK. *Keram. & Steklo*, **12** [10] 15–16 (1936).—Experiments showed that chrome-plated molds used in the manufacture of drinking glasses are much more durable than ordinary molds and improve the quality of the glassware. M.V.C.

**Classification of tank furnaces.** S. S. BERMAN. *Glass Ind.*, **17** [9] 309–12; [10] 346–48 (1936).—B. lists under tank division the furnace with a single chamber, furnaces with divided chambers which include furnaces with a dog-hole and separate crowns (Malyshev's furnace with a wasp shape tank), furnaces with a dog-hole (throat) and one common crown (American design), and furnaces with a lateral construction. The presence of regenerators and recuperators, the direction of the flame, the outline of the tank, and (in furnaces with a dog-hole) the depth of the tank are discussed. Illustrated. E.J.V.

**Colored glasses and their ability to protect against light.** AXEL JERMSTAD AND OTTAR OSTBY. *Arch. Pharm. Chem.*, **92**, 463–66 (1935); *Chem. Abs.*, **29**, 7599 (1935).—In view of the increasing number of substances which, according to the pharmacopeia, are to be protected from light, the present work was undertaken to determine which colors render the best protection against the actinic rays. Differently colored glass bottles were filled with 2% KI solution to which had been added 4% dilute $H_2SO_4$ (Møller, *Ber. Deut. Chem. Ges.*, **10**, 170 (1900)) and exposed for $^1/_2$ hr. to ultra-violet light from a quartz lamp and 1 hr. to sunlight, respectively. The amount of I separated was then determined in 50 cc. of the solution by titrating with 0.01 *N* $Na_2S_2O_3$. A maximum separation of 1.5 mg. I after 1-hr. exposure to sunlight is considered permissible for a satisfactory light-protecting glass (van der Wielen, Scrøder's Leerboek der Recepteerkunde, p. 9 (1929)). In accordance with this, the experiments show that black-, red-, and all brown-colored glasses were

satisfactory, black giving no separation, red a slight trace in ultra-violet light as well as sunlight, and brown from a slight trace to 1.10 mg. I in ultra-violet light and from a slight trace to 0.50 mg. I in sunlight. In view of the inconvenience of black glass and the high price of a satisfactory red glass, the brown is recommended. Blue and green glasses appeared to vary in quality and did not render sufficient protection in every case.

**Continuous and repeated melting of glass.** K. FUWA. *Jour. Japan. Ceram. Assn.*, **42**, 200 (1934); *Brit. Chem. Abs.-B*, **55** [9] 192 (1936).—The $Al_2O_3$ and $Fe_2O_3$ content of glass increases abruptly after a certain time of melting, owing to pot corrosion. The glass becomes nonuniform as a result.

**Decorative white enamel for glass.** S. I. RUBINOVA. *Keram. & Steklo*, **12** [11] 29–31 (1936).—R. discusses the general properties of the enamel used (particularly its opacification and the opacifiers used), the manufacture of such an enamel, the effect of raw materials, and directions for the grinding and application of the enamel on glass surfaces. M.V.C.

**Effect of batch materials on the decolorization of glass by selenium.** WILLIAM HORAK. *Glass Ind.*, **17** [11] 379–81 (1936).—Test batches of glass in three groups of varying selenium content were made up and melted so as to have as nearly the same thermal treatment as possible. The results obtained led to the following conclusions: (1) The effect of introducing sulfate into a glass containing selenium is to decrease the color from a given quantity of selenium. (2) The introduction of 1% $B_2O_3$ into such a glass deepens the pink color just about enough to make up for the decrease due to sulfate. (3) The introduction of 1% BaO into sulfate-containing glass deepens the pink color to a greater extent than does $B_2O_3$. (4) The introduction of either BaO or $B_2O_3$ into a glass does not require an increase in selenium to maintain a given degree of decolorization. The selenium content generally must be reduced. E.J.V.

**Effect of cullet on reactions of glass formation.** M. A. BEZBORODOV, N. D. ZAVYALOV, AND E. N. ZELIGER. *Keram. & Steklo*, **12** [10] 26–30 (1936); see *Ceram. Abs.*, **15** [10] 298 (1936). M.V.C.

**Effect of increased strength of thin filaments.** S. N. ZHURKOV. *Tech. Phys. U.S.S.R.*, **1**, 389–99 (1934); *Zhur. Tekh. Fiz.*, **4**, 1640–53 (1934); *Chem. Abs.*, **29**, 8260 (1935). —Thin filaments of glass and quartz, after removal of the "oriented" surface layer by treatment with $H_2F_2$, showed increased tensile strength. Rupture is due to discontinuities, especially those on the surface. Measurements were made on glass, quartz, and Pyrex brand glass.

**Engineering aspects of European glass plants.** J. EARL FRAZIER. *Glass Ind.*, **17** [11] 373–74 (1936).—At the Charlton Works of the United Glass Bottle Manufacturers, Ltd., England, sillimanite slip cast flux blocks are used, with excellent results, in side walls and in the bottom of the melting ends. These are between the ordinary flux blocks and Corhart cast block, both in cost and density. Electric leers of the 4-ft. wide variety, having the electrical elements placed on the sides of the leers, are used. Rotary screw propeller-type batch chargers are popular. The equipment and designs to be found in several other European glass plants are also described. E.J.V.

**Factory glazing development, Thermolux.** GRAHAM CUNNINGHAM. *Synthetic & Applied Finishes*, **6** [68] 201 (1935); abstracted in *Sprechsaal*, **69** [5] 64 (1936).—The new type of laminated glass, Thermolux, developed by P. Modigliani, transmits sunlight without sun heat and yet provides undistorted transmission of the visible wavelengths of the spectrum, imparting to all colors their true values. It consists of two sheets of plain glass with a central interlayer of numerous spun glass silk threads regularly arranged. This central lamina is porous and varies in thickness from 1 mm. to 3 mm., and the edges are hermetically sealed. This laminated glass is normally white with a satin-like sheen, but it may have other coloring. Heat and glare are avoided in summer, while artificial light and heat are conserved during the winter. Thermolux is used in Italy in public buildings, etc. M.V.C.

**Furnaces for melting optical and technical glasses.** E. YA. YURCHENKO AND K. T. BONDAREV. *Keram. & Steklo*, **12** [10] 18–21 (1936).—Y. deals with the characteristics of furnaces of Ivanovskiĭ and Groum-Grjimailo fired with fuel oil and used for melting optical and technical glasses in U.S.S.R. Advantages of using gas-fired furnaces are enumerated. M.V.C.

**Fused silica, its recent development and application.** G. E. STEPHENSON. *Chem. & Ind.*, **55** [20] 389–95 (1936).—Developments made during the last five years and earlier unpublished work are stressed. Maintenance of constant temperatures in acid-pickling and plating baths is possible by the use of new Vitreosil electric immersion heaters. In thermostat regulators a solid rod of fused silica stands in a metal tube, and by the difference in expansion of these materials the make and break of current for electrically heated furnaces is made. The mechanical properties of fused silica are tabulated. Results of breaking tests vary widely. The high value of fused silica as an insulator has led to interesting applications. Optical properties and applications are discussed. 20 references. G.R.S.

**Glass fiber.** JOHN H. THOMAS. *Glass Ind.*, **17** [9] 295–96 (1936).—Glass fibers are being made commercially in diameters of 0.010 in. to 0.00005 in.; as the diameter decreases very interesting strengths are developed. Tests on filaments 0.0005 in. in diameter show a tensile strength of approximately 250,000 lb./in.$^2$ The diameter of a 60 filament thread is 0.0067 in., breaking at 17,000 lb./in.$^2$ If the sum of the areas of the 60 filaments is taken as a basis, the breaking load is 247,000 lb./in.$^2$ No strain has been detected in fiber below a diameter of 0.001 in., though unannealed. A fiber of 0.00005-in. diameter has 8,740,000 sq. in. of surface /lb. The length of a pound of 0.00005-in. fiber is approximately 24,000 miles. Apparatus developed to determine the tensile strength of very fine fibers is described in detail, and applications of glass fibers are listed. Illustrated. E.J.V.

**Glasses colored by carbonaceous matter: IV.** K. FUWA. *Jour. Soc. Chem. Ind. Japan*, **39** [11] 398–400B (1936).—The quantitative determination of carbon in glasses colored with carbonaceous matter is given. For Parts **I–III** see *Ceram. Abs.*, **16** [3] 86 (1937). M.V.C.

**Glassmaking minerals.** C. S. FOX. *Records Geol. Survey India*, **70**, 397–405 (1935).—The sources of the essential raw materials in India, the indigenous glass industry, and the modern glass industry in India and

the glassware made therein are described. Some batch mixtures in use in India are given, and the advantages and disadvantages in glass manufacture of alumina in the sand used are detailed. No plate glass, glass tubing, or special glassware, such as optical, heat-resisting, or laboratory glassware, appears to be made in India in commercial quantities. The Indian glass industry, according to F., appears to consist of independent firms with no coöperation between them. There is room for coördination and for improvement in methods of manufacture, quality of materials, and in various economies—both in a better knowledge of the available raw materials and in increasing sales by studying markets. At present it is difficult to secure detailed statistics of production and of the quality of raw materials, etc., utilized. Except for the alkali (soda) and certain chemicals, practically everything else for this industry, including furnace materials, is available in India. A.P.S.

**Glass, a new German construction material for the chemical industry.** K. von Stoessner. *Chem. Fabrik*, 9 [39–40] 443–45 (1936).—The importance of glass for the chemical and brewing industry and distilleries is stressed. Many parts such as heavy acid containers, pipings, etc., may be made from glass but such glass must, in many of its properties, excel the common types of glass. The Jena Works have developed such special glasses. S. suggests some instances where glass may be substituted for metal parts. Illustrated. L.E.T.

**Glass records for talking clock.** Doré Silverman. *Discovery*, 17 [202] 315–17 (1936).—London telephone users, by dialing T-I-M, may learn the exact time from the talking clock invented by the Anglo-Hungarian, Wender. The time is spoken from glass disks, glass being chosen as the most durable of transparent materials. A schematic diagram is given. H.H.S.

**Glass silvering solution: I.** K. Nakanishi. *Jour. Japan. Ceram. Assn.*, 42, 11–20 (1934); *Jour. Soc. Glass Tech.*, 18, 200A (1934).—Excess silver nitrate in the $AgNO_3$-$NH_4OH$ solution retards mirror formation and diminishes brilliancy, while excess ammonia diminishes the amount of silver available for deposition. Under optimum conditions 95% of the silver in solution is available for deposition. With the use of potassium sodium tartrate, a ratio greater than 5 to 1 of silver nitrate is unnecessary. The time required for silvering decreases with increasing concentration of the solutions.

**High-speed cutting of glass disks.** R. H. Zinszer. *Rev. Sci. Instruments*, 7, 156 (1936).—In cutting thick glass disks, the cutting time per disk was reduced from two hours to thirty minutes by making frequent but short contacts between the glass which was being cut and the rapidly rotating brass cylinder used as a cutting tool. The abrasive was No. 40 Carborundum. Frequent slushing with water was necessary in order to wash away the particles of ground glass. The increased speed of the rotating cylinder together with short contacts between the cylinder and glass decreased cutting time. H.E.S.

**Increasing output of Lynch machines.** Ya. A. Shkolnikov, M. G. Chernyak, and V. G. Yaschevskiĭ. *Keram. & Steklo*, 12 [8–9] 6–16 (1936).—Details of technical changes made in Lynch machines to increase their production capacity are given. The composition of glass was altered by increasing its magnesia content. The results were satisfactory. M.V.C.

**Investigation of the amorphous state.** P. Kobeko and E. Kuvschinski. *Tech. Phys. U.S.S.R.*, 3 [6] 508–10 (1936); abstracted in *Physik. Ber.*, 17 [21] 1966 (1936).—The different temperature stages occurring in the melting of glass were studied. The following definite temperature points were determined: appearance of the yellow sodium luminescence 525°C; beginning of drawability and softening 580 to 680° according to type of glass; working temperature 750 to 850°C; and formation of C deposit 450°C. The equalization of strains in the glass and the expansion coefficients are discussed. M.H.

**Liberation of gases from vitrifiable mixtures containing both sodium sulfate and carbonate.** H. Jebsen-Marwedel. Translated in *Glass Ind.*, 17 [9] 297–302 (1936); for abstract see *Ceram. Abs.*, 16 [1] 13 (1937). E.J.V.

**Manufacture of headlamps and signal glasses.** M. A. Caricyn and M. G. Chernyak. *Keram. & Steklo*, 12 [11] 1–7 (1936).—The manufacture of various types of dispersing and colored technical glasses in Russia is discussed together with their composition, conditions of melting, working, and testing. M.V.C.

**Manufacture of special glasses in the Weisswasser Osram Glass Works O/L.** R. Schmidt. *Osram-Nachrichten*, 18 [5] 89–92; [6] 115–18 (1936); abstracted in *Referat. Silikatliteratur*, 3 [11] 3477 (1936).—Manufacturing processes are described in the first part. The second section deals with the properties and application of special glasses, which are divided into 7 groups: (1) difficultly fusible and chemically, thermally, and mechanically resistant glasses (aluminoborosilicate, molybdenum, and tungsten for electrotechnical uses), (2) easily fusible but resistant glasses, (3) Thuringer apparatus glass, (4) glasses resistant to metallic vapor, (5) glasses permeable to different rays, (6) glasses absorbing Röntgen rays, and (7) colored glasses. M.V.C.

**Melting glass in a tank furnace of the Kuzmich and Trusov type.** A. A. Il'inskiĭ and F. G. Solinov. *Keram. & Steklo*, 12 [11] 12–17 (1936).—Details of operation of a new tank furnace constructed by Kuzmich and Trusov are given. Illustrated. M.V.C.

**Methods of moistening sand to obtain a homogeneous batch.** S. Ya. Raf. *Keram. & Steklo*, 12 [10] 11–15 (1936).—Reasons for moistening the batch are enumerated, and the methods used are dealt with. M.V.C.

**Osram apparatus glass in the draft beer industry.** A. Fehse. *Osram-Nachrichten*, 17 [11] 245–48 (1935); abstracted in *Referat. Silikatliteratur*, 3 [11] 3449 (1936).—One of the most promising fields of application for glass as a substitute for metal, which must be imported in Germany, is in the installations for the high-pressure piping of beer. The advantages of this use of apparatus glass are given. M.V.C.

**Phosphorescence of glass solarized by soft X-rays.** H. Kersten and C. H. Dwight. *Jour. Optical Soc. Amer.*, 24, 285–86 (1934); *Phot. Abs.*, 14, 227 (1934); *Chem. Abs.*, 29 [5] 1322 (1935).—Samples of glass were exposed to X-rays for various times and placed in contact with photographic film for a definite time; the resulting densities were measured by means of a photoelectric cell; this gives the "phosphorescence yield." Samples were also exposed

for a definite time and placed in contact with the film for various times; the densities were measured. This gives the "phosphorescence decay." The yield and decay curves are of the same shape as those found by Swindells for $CaWO_4$. It is concluded from comparison with previous work that there will be correlations between solarization and phosphorescence and the decay of these effects. See "Solarization—," *Ceram. Abs.*, **14** [10] 246 (1935).

**Plant method for viscosity measurements of glass.** WILLI M. COHN. *Glass Ind.*, **17** [11] 375–76 (1936).—An improved Stoke's law for a liquid in a crucible is as follows:

$$\eta = \frac{2gR^2(d_1-d_2)\left(1-\frac{R}{r}\right)^{2.25}}{9u\left(1+3.3\frac{R}{h}\right)}$$

in which $\eta$ = the viscosity, $g$ = the gravity, $R$ = the radius of the sphere, $r$ = the radius of the container with the melt, $d_1$ and $d_2$ = the densities of the sphere and melt, $u$ = the rate of fall of the sphere, and $h$ = the height through which the sphere falls. A crucible, 6 in. in height and 2 in. in diameter, of a highly refractory material such as sillimanite, is placed in a furnace. The glass is melted in this crucible until free of bubbles, and then cooled to the temperature when it is in a semiliquid state. After the melt has reached a temperature equilibrium, measured by means of one or two thermocouples, a sphere of 80% platinum-20% rhodium of about 10 mm. diameter is dropped into the melt. After a certain length of time, *e.g.*, 60 min., a second sphere and after 120 min. a third sphere are dropped into the melt. About 120 min. after the dropping of the third sphere, the crucible is quickly removed from the furnace and cooled in Sil-O-Cel powder. On cooling to room temperature, the crucible is split along its axis and the distance traveled by the spheres is measured. These data give the rate of fall, $u$, in the middle part of the crucible. Inserting the correct values and constants in the formula gives the viscosity of the glass at this particular temperature. Viscosity values obtained were reproducible, the maximum deviation being ±3%. Application of this method to tanks is discussed. See *Ceram. Abs.*, **14** [8] 196 (1935).

E.J.V.

**Process of dissolving grog particles in soda-lime glasses.** N. S. MANUĬLOVA. *Keram. & Steklo*, **12** [10] 31–34 (1936).—Grog stones dissolve very well in glass, undergoing a series of transformations, beginning with a whitish-yellow grain of grog and finally changing into a small transparent and drop-like formation called "eye" or "knot." This process depends on a series of causes, such as (1) time the grog is in the glass melt, (2) rate of diffusion between the materials of the stone and those of the glass, (3) alkalinity of glass, (4) temperature, (5) viscosity, etc. The grog stone begins to dissolve in its periphery with a dissolving of mullite and concentration of alumina. Corundum changes into nepheline or carnegieite and the latter gradually dissolves in the glass. Nepheline often disappears without leaving any traces, while carnegieite leaves always tiny crystals of cristobalite. Details are given. Illustrated.

M.V.C.

**Production of opaque glasses dispersing light.** S. M. BREKHOVSKIKH. *Keram. & Steklo*, **12** [11] 7–10 (1936).—The glass used is classified as a special milk glass called "opaque opal" because of its appearance, optical properties, and character of opacification. The minimal undispersed permeability of this glass is obtained by a high alumina content. Lowering of the $Al_2O_3$ content produced transparent glasses. CaO and $B_2O_3$ greatly lower the effect of opacification and increase permeability to light of the glass. Increase of the $K_2O$ for $Na_2O$ increases transparency and the opalescence of glass. Opacification required was obtained by introducing CaO as dehydrated gypsum. Replacement of gypsum by other calcium salts did not produce the necessary opacity. The introduction of MgO, even in small amounts, destroyed the effect of opacification, making the glass transparent. Small quantities of arsenic promote the burning of the opacifiers. Replacement of lead oxide by barium and zinc oxide lowers the effect of opacification. The glass must be annealed between 380 and 400°C. At an annealing temperature of 440°, opacifiers burn out, and at 460 or 470° glass becomes almost transparent with a weak blue color tone. This is probably due to a decrease in size of particles of the opacifier. The character of firing must be reducing as, with an oxidizing flame, opacifiers burn out more rapidly. The addition of cullet lowers the effect of opacification.

M.V.C.

**Proper construction of burners for glass furnaces.** M. D. TAMARIN AND A. S. RUGA. *Keram. & Steklo*, **12** [10] 16–18 (1936).—The correct position of burners in glass furnaces is discussed in detail. Illustrated.

M.V.C.

**Reaction of glass upon orthotoluidine.** D. W. HORN. *Amer. Jour. Pharm.*, **108**, 324–25 (1936); *Analyst*, **61**, 792 (1936).—Orthotoluidine in contact with glass produces a yellow color indistinguishable from that given when *o*-toluidine and "active chlorine" interact. The color is more pronounced with long standing, heating, or autoclaving.

H.H.S.

**Relations between drawing temperature of glass, flow index, and the specific melting capacity of tanks.** K. METZGER. *Glastech. Ber.*, **12**, 381–85 (1934); *Chem. Abs.*, **29** [3] 897 (1935).—The following formula is developed: $L/F = 1/N \cdot q/c \cdot (1-F_s/F)/(t_s-t_e)$, where $L/F$ represents the specific melting capacity in kg./sq. m./hr.; $L$ is the hourly capacity in kg./hr.; $n$ is flow index (which shows how much more glass flows from the melting to the working end than is worked out); $c$ is the specific heat of the glass in kg.-cal./kg. (its value is 0.28 if the same temperature is assumed for melting and drawing); $q$ is the hourly heat loss in kg.-cal./sq. m. of the crown and the side walls of the unheated parts related to 1 sq. m. of unheated hearth surface (this value can be taken as around 10,000 kg.-cal./sq. m./hr.); $t_s$ is the melting temperature (usually 1400°); $t_e$ is the working temperature of the glass; $F$ is the total hearth surface in sq. m.; and $F_s$ is the heated hearth surface (melting surface) in sq. m.

**Resistance of glass plates to wind pressure.** N. MATSUO. *Jour. Japan. Ceram. Assn.*, **41**, 188–99 (1933); *Jour. Soc. Glass Tech.*, **18**, 213A (1934).—For the same thickness of plate the resisting power is approximately inversely proportional to the area. The following average bending strengths are given: 2-mm. plates, 732 kg./sq.

cm.; 3-mm. plates, 562 kg./sq. cm.; 5-mm. plates, 467 kg. /sq. cm.; and 6-mm. plates, 423 kg./ sq. cm. In thin plates fractures extend over the whole sheet, but for thick, small plates fractures are generally confined to the center.

**Rôle of chemistry in polishing processes.** I. V. GREBENSHCHIKOV. *Sotsialist. Rekonstruktsiya i Nauka*, No. 2, pp. 22–23 (1935); *Chem. Abs.*, **29**, 8173 (1935).—A theory is given of polishing based on the chemical nature of the substances employed. The greatest thickness ($166 \times 10^{-8}$ cm.) of a polished layer of glass is obtained by polishing with acidulated water of $p_H$ 3.8, and the smallest ($4 \times 10^{-8}$ cm.) is obtained with transformer oil. Some salts in a 1% solution exercise a specific influence; $NH_4F$ retards glass polishing. $H_2O$ acts hydrolytically upon the polished surface of the glass (as well as upon basalt and feldspar), covering it with a protective colloidal film of silicic acid 14 to 70 A. thick. $Fe_2O_3$ calcined at 750° at the highest dispersion is adsorbed simultaneously by the $SiO_2$ film and by the surface of the rosin polishing composition. In polishing metals a protecting film of oxides is formed. The polishing of a steel sample either in a H atmosphere or by connecting it with the cathode is slower than in a mixture of $H_2$ with $H_2S$, in the air, or by connecting it with the anode. The polishing powders, the best being $Cr_2O_3$ from $K_2Cr_2O_7$ and S, absorb the fat parts of the stearic acid molecule used as a metal lubricant and distributed on it in unimolecular layers. The acid parts of the molecules of this acid are combined with the surface oxides of the metals. The connection established, therefore, between the metal and the polishing material is broken during the movement of the metal and then reëstablished.

**Safety glass and its application to building.** W. KAEMPFFERT. *N. Y. Times*, p. 8XX (Jan. 10, 1937).—Ordinary glass is "casehardened" by being heat-soaked to about 1150°F and suddenly chilled by a blast of cold air. After this treatment, the glass can not be drilled or otherwise worked without disrupting into little blunt-edged cubes which, however, remain in one plane and tend to interlock. A light sharp blow from a hammer will disrupt this new glass, while a half-pound steel ball dropped from a height of 10 ft. bounces off without breaking the plate. The glass is $4^1/_2$ times as strong as ordinary glass and it will bend a little. M.V.C.

**Separation by decantation of liquid layers in molten boro-alkaline-earth glasses.** M. A. FOEX. *Compt. Rend.*, 202 [19] 1582–84 (1936).—Most of the boric glasses, especially those of the lime, strontium, and barytes type, show two liquid layers between certain limits of concentration and temperature. In all cases, the upper layer presents in cooling a vitreous and opalescent aspect. The conditions for this separation as functions of lime concentration were investigated for a boro-calcic glass by means of electric conductivity measurements. The results are shown in curves from which it can be concluded that, for a given temperature, the ratio of the densities of the two layers is constant in the alkaline-earth glasses. M.H.

**Two-layer thermal insulation of tank furnaces.** S. S. BERMAN. *Keram. & Steklo*, 12 [8–9] 21–26 (1936).—B. presents computations for two-layer thermal insulation of tank furnaces. M.V.C.

**Types of furnaces used for sheet glass manufacture.** F. S. ENTELIS. *Keram. & Steklo*, 12 [8–9] 17–20 (1936).—The Gobbe and Berman furnaces are dealt with. M.V.C.

**Using Fourcault machines in the manufacture of colored signal glasses.** V. G. SEMENOV. *Keram. & Steklo*, 12 [11] 10–11 (1936).—S. describes experiments in using Fourcault machines for the production of colored signal glasses. The results are tabulated. M.V.C.

**Variation of the refractive index of unannealed glass as a function of time.** NIUTA KLEIN. *Compt. Rend.*, **201**, 339–41 (1935).—Further results of an investigation (*Ceram. Abs.*, **14** [11] 275 (1935)) are given, and an equation is derived to determine the variation of the index with temperature. M.H.

**Viscosity of glass.** P. GILARD, L. DUBRUL, G. HENRY, SCOHY, AND PIÉRET. *Bull. Soc. Chim. Belg.*, **45** [4] 131–76; [5] 379–437 (1936).—An exhaustive survey undertaken by the (Belgian) National Fund for Scientific Research discusses the characteristics and properties of the viscous and vitreous state in glass in the light of recent investigations and gives the numerical values obtained in the results for the viscosity of different types of glass, the effects of thermal treatment, and the change of viscosity as a function of temperature. Instruments and testing methods are described in detail. 75 references. M.H.

BOOK AND BULLETIN

**Dielectric losses in glasses at high frequency.** E. A. KRAKAV. State Energo Publishing House, Leningrad, 1932. 6 pp., 3 figs. Reviewed in *Jour. Soc. Glass Tech.*, **18**, 228–29A (1934).—Dielectric losses at a frequency of $2 \times 10^{-7}$ oscillations per second were determined by making a test tube of the glass, filling it with mercury, and placing it in a Dewar's vessel with mercury. A thermometer was immersed in the test tube. An electrode was introduced in the mercury in the Dewar's container, another into the test tube. Curves representing the rise in temperature as a function of time determined the amount of heat developed in the calorimeter in consequence of dielectric losses for a definite unit of time. Results for several glasses are given.

**General Technology of Glass Manufacture.** M. A. BEZBORODOV. Gizlegprom., 1936. 261 pp., 88 illustrations. Reviewed in *Keram. & Steklo*, **12** [11] 38 (1936).—B. describes, in a clear and simple way, the theoretical and technical sides of the technology of glass for workmen and minor officials of glassworks. M.V.C.

PATENTS

**Apparatus for:**

**Casehardening glass.** R. S. HINSEY (Libbey-Owens-Ford Glass Co.). U. S. 2,068,746, Jan. 26, 1937 (May 4, 1935).

**Making curved safety glass.** E. H. HAUX (Duplate Corp.). U. S. 2,068,104, Jan. 19, 1937 (Feb. 23, 1935).

**Tempering glass.** PILKINGTON BROS., LTD., AND L. J.-B. FORBES. Brit. 457,475, Dec. 9, 1936 (May 29, 1935).

**Tempering glass sheets.** AMERICAN SECURIT CO. Brit. 459,870, Jan. 27, 1937 (July 16, 1934).

**Testing electric-lamp bulbs, etc., for leaks.** BRITISH THOMSON-HOUSTON CO., LTD. Brit. 457,954, Dec. 23, 1936 (Dec. 12, 1934).

**Borosilicate glass containing cerium.** H. P. HOOD (Corning Glass Works). U. S. 2,068,801, Jan. 26, 1937 (July 30, 1935). A borosilicate glass containing a substantial amount of cerium also contains not more than 10% of alkali oxide and a substantial amount of an oxide of the group consisting of barium oxide and zinc oxide.

**Coloring agents for glass batches and method of employing.** E. I. DU PONT DE NEMOURS & CO. Brit. 459,886, Jan. 27, 1937 (July 18, 1934).

**Composition for etching and etching transfers.** NANCE CLAYTON-KENNEDY. U. S. 2,067,925, Jan. 19, 1937 (March 7, 1934). An etching composition for etching glass comprises an acid fluoride disseminated through a carrier medium consisting of cornstarch, black treacle, sugar syrup, gum senegal, gum tragacanth, carbon black, finely ground magnesium carbonate, and a glycerine containing plasticizer, the proportions being such as to produce a composition sufficiently elastic and firm to permit printing or transfer to glass without blurring during the printing or for a sufficient period to permit etching.

**Cooling devices for tempering glass.** HERZOGENRATHER GLASWERKE BICHEROUX & CIE, GES. Brit. 458,790, Jan. 7, 1937 (March 9, 1935).

**Cover glass.** S. L. LEBBY (Corning Glass Works). U. S. 2,068,805, Jan. 26, 1937 (Feb. 4, 1935).

**Devices for molding glass under pressure.** W. REDLHAMMER. Brit. 458,556, Jan. 7, 1937 (May 1, 1936).

**Furnace.** L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 2,069,542, Feb. 2, 1937 (Feb. 23, 1935).

**Glassblowing machine.** E. G. BRIDGES (Lynch Corp.). U. S. 2,069,130, Jan. 26, 1937 (June 4, 1917; July 16, 1927).

**Glass building block.** D. E. GRAY (Corning Glass Works). U. S. 2,068,798, Jan. 26, 1937 (May 21, 1934).

**Glassmaking apparatus and method.** VERGIL MULHOLLAND (Hartford-Empire Co.). U. S. 2,068,925, Jan. 26, 1937 (June 13, 1934).

**Glass-to-metal seal.** E. E. BURGER AND A. W. HULL (General Electric Co.). U. S. 2,071,196, Feb. 16, 1937 (Jan. 4, 1934).

**Glass mold.** ANTHONY ROSA. U. S. 2,070,493, Feb. 9, 1937 (April 17, 1935). A portable glass mold for the blowing of glassware is described.

**Glass tank feeding shelf.** F. G. SCHWALBE (Toledo Engineering Co., Inc.). U. S. 2,068,515, Jan. 19, 1937 (April 15, 1935).

**Laminated glass and process of making.** J. H. SHERTS (Duplate Corp.). U. S. 2,068,082, Jan. 19, 1937 (June 8, 1935).

**Machine for forming glassware.** T. F. PEARSON. Brit. 458,666, Jan. 7, 1937 (March 23, 1935).

**Machine for forming hollow glass containers.** L. D. SOUBIER (Owens-Illinois Glass Co.). U. S. 2,069,541, Feb. 2, 1937 (Aug. 1, 1934).

**Manufacture of glass wool.** D. C. SIMPSON (Owens-Illinois Glass Co.). U. S. 2,068,202, Jan. 19, 1937 (Nov. 29, 1932; renewed March 25, 1936).

**Manufacture of laminated glass, etc.** A. KÄMPFER. Brit. 458,608, Jan. 7, 1937 (Oct. 1, 1934).

**Manufacture of laminated glass.** C. S. SHOEMAKER (American Window Glass Co.). U. S. 2,069,425, Feb. 2, 1937 (June 8, 1936). In the manufacture of laminated glass the steps consist in forming a film of a solution of a polymerized acrylic acid ester on a glass sheet, thereafter drying the film on the glass sheet by heat, forming a film of dibutyl phthalate on the coating on the glass sheet, forming a sandwich of the coated glass sheet and a second similarly coated glass sheet with the strengthening material therebetween, and thereafter, without the application of heat, subjecting the sandwich to pressure and permitting it to cool down under pressure.

**Manufacture of unstable glasses.** GENERAL ELECTRIC CO., LTD., AND J. H. PARTRIDGE. Brit. 458,042, Dec. 23, 1936 (July 18, 1935).

**Means for and method of applying color to molded glass articles.** A. G. REZ. U. S. 2,067,949, Jan. 19, 1937 (Feb. 20, 1933). (1) The method of coloring a molded glass article during the period of its manufacture consists in directing a fusible coloring pigment against the parts to be colored following removal of the article from the mold and at a location in its course of travel at which its initial molding heat will have decreased to the fusing temperature of the pigment. (9) The combination with a machine for molding glass articles, a leer for annealing the articles, a pigment-applying machine, including a stencil disposed intermediate the molding machine and the leer, means for conveying the articles from the molding machine to the pigment-applying machine and from the pigment-applying machine to the leer, and means operating on the articles between the molding machine and the pigment-applying machine for modifying the initial molding heat of the article, the pigment-applying machine being movably mounted relative to the molding machine and the leer, whereby the pigment-applying machine may be positioned so that the initial molding heat retained in the articles at the time the articles are submitted to the action of the pigment-applying machine will be suitable to cause the pigment contacting with the articles to be fused therewith within the areas defined by the stencil.

**Method and apparatus for annealing glassware.** D. G. MERRILL (Hartford-Empire Co.). U. S. 2,068,923, Jan. 26, 1937 (Nov. 8, 1935).

**Method and apparatus for manufacturing and fabricating glass wool.** D. C. SIMPSON (Owens-Illinois Glass Co.). U. S. 2,068,203, Jan. 19, 1937 (Oct. 27, 1933; renewed March 25, 1936).

**Method and apparatus for the manufacture of hollow glass articles.** E. G. BRIDGES (Lynch Corp.). U. S. 2,071,295, Feb. 16, 1937 (Dec. 28, 1929).

**Method and apparatus for tempering glass.** F. A. CLEMO (American Securit Co.). Brit. 457,488, Dec. 9, 1936 (May 30, 1935).

**Method of:**

**Feeding glass and an apparatus therefor.** S. G. STUCKEY (Obear-Nester Glass Co.). U. S. 2,069,982, Feb. 9, 1937 (April 7, 1934).

**Forming hollow glassware.** HARTFORD-EMPIRE CO. Brit. 458,231, Dec. 31, 1936 (May 24, 1935).

**Frosting glass articles.** H. STERNER. Brit. 458,115, Dec. 23, 1936 (April 16, 1936).

**Producing decorative designs on glass.** J. C. CORSAN AND LONDON SAND BLAST DECORATIVE GLASS WORKS, LTD. Brit. 457,953, Dec. 23, 1936 (Nov. 27, 1935).

**Producing laminated glass.** A. KÄMPFER. Brit. 457,345, Dec. 9, 1936 (June 9, 1934).

**Mold for the manufacture of glass vessels.** VERRERIES GOBELETERIES L'ESPERANCE SOC. ANON. Brit. 458,630, Jan. 7, 1937 (Feb. 2, 1935).

**Plastic for laminated safety glass.** G. B. WATKINS AND J. D. RYAN (Libbey-Owens-Ford Glass Co.). U. S. 2,068,782, Jan. 26, 1937 (June 28, 1934).

**Plate glass surfacing car.** WILLIAM OWEN (Pittsburgh Plate Glass Co.). U. S. 2,068,068, Jan. 19, 1937 (April 30, 1936).

**Process for the manufacture of refractory products.** V. M. GOLDSCHMIDT. Brit. 458,407, Dec. 31, 1936 (June 14, 1935).

**Production of glass articles.** WURTTEMBERGISCHE METALLWARENFABRIK AND H. DEBACH. Brit. 459,201, Jan. 13, 1937 (Sept. 7, 1935).

**Production of glass bodies, particularly glass shells, with an indrawn rim.** WURTTEMBERGISCHE METALLWARENFABRIK AND H. DEBACH. Brit. 459,200, Jan. 13, 1937 (Sept. 7, 1935).

**Refractory glasses.** GENERAL ELECTRIC CO., LTD., AND J. H. PARTRIDGE. Brit. 458,881, Jan. 13, 1937 (Nov. 11, 1935). Brit. 459,065, Jan. 13, 1937 (Nov. 25, 1935).

**Regenerator tank and method of operating.** VERGIL MULHOLLAND (Hartford-Empire Co.). U. S. 2,068,924, Jan. 26, 1937 (Dec. 2, 1932).

**Safety glass.** CARBIDE & CARBON CHEMICALS CORP. Brit. 460,230, Feb. 3, 1937 (Aug. 29, 1934).

**Tempering glass.** E. M. GUYER (Corning Glass Works). U. S. 2,068,799, Jan. 26, 1937 (Sept. 2, 1933). The method of tempering a glass body includes heating it by creating dielectric losses within it and cooling its surface while it is being so heated.

**Tempering of plates of glass.** PILKINGTON BROS., LTD., AND L. J.-B. FORBES. Brit. 457,537, Dec. 9, 1936 (May 31, 1935).

## Structural Clay Products

**Berlin's use of stoneware.** FELIX SINGER. *Clay Prod. Jour. Australia*, **4** [3] 17 (1937).—Berlin sewerage is constructed only from stoneware of the first quality. During the building of an underground railway in Berlin, stoneware pipes laid down 45 years previously had to be excavated. They were all in first class condition. See *Ceram. Abs.*, **14** [7] 164 (1935). H.H.S.

**Brick road paving.** G. N. HODSON. *Chem. & Ind.*, **55** [24] 472–74 (1936).—The history of brick roads is briefly outlined. The practice of laying a brick pavement in the U. S. is treated under the following points: (1) drainage, (2) curbs, (3) natural bases, (4) artificial bases, (5) bedding course, (6) brick, and (7) asphalt filler. The methods of constructing and testing experimental brick roads in England are described. G.R.S.

**Elimination of efflorescences in tile and brick.** M. BIGEON. *Congr. Chim. Ind., 14th Congress, Paris, 1934*, 2 pp.; *Chem. Abs.*, **29**, 6379 (1935).—The formation of $CaSO_4$ efflorescences can be prevented by adding 2 to 6 kg. of precipitated $BaCO_3$ per ton of clay.

**Pipes for sewerage purposes.** ANON. *Clay Prod. Jour. Australia*, **4** [3] 6 (1937).—The Inst. of Engineers of Australia has appointed a committee of enquiry into the merits of different makes of pipes for sewerage purposes. H.H.S.

**Stoneware's worst obstacle.** ANON. *Clay Prod. Jour. Australia*, **4** [3] 8 (1937).—The greatest obstacle encountered by protagonists for stoneware pipes is the highly trained young university graduate. He regards a stoneware pipe as just a stoneware pipe; there is nothing to be learned from it. A concrete pipe, however, has proportions of sand and cement and interstices; small test blocks can be made, it can be designed and constructed, and its breaking load can be predicted. Thus it is an object of interest and study. H.H.S.

**Super-ceramic building members.** F. O. ANDEREGG. *Jour. Amer. Ceram. Soc.*, **20** [3] 77–79 (1937).

PATENT

**Manufacture of brick.** G. E. ROGERS. Brit. 457,884, Dec. 23, 1936 (June 4, 1935).

## Refractories

**Ceramics in India: Potteries and fire brick.** EDITORIAL. *Indian Eng.* (Special Supp.), pp. 41–42 (Dec., 1936).—The gradual expansion of the Raneegunge Pottery Works and the Reliance Firebrick and Pottery Co., Ltd., and the development *pari passu* of the Indian ceramic industry are reviewed. These two works have practically rendered the Indian iron and steel industry independent of imported fire brick. A.P.S.

**Cristobalite.** D. S. BELYANKIN AND N. G. KAZNAKOVA. *Trav. Inst. Petrog. Acad. Sci. U.R.S.S.*, **6**, 362–68 (1934); *Jour. Soc. Glass Tech.*, **20**[77] 6A (1936).—Cristobalite from the zones of silica brick from an open-hearth furnace was examined. A stable form was found in that end of the brick which had been in direct contact with the furnace gases at temperatures higher than 1470° and a metastable form due to the process of firing in the manufacture of silica brick at temperatures lower than 1470°.

**Effect of manufacturing factors on properties of grog brick with a high grog content.** R. MAKHL. *Keram. & Steklo*, **12** [8–9] 26–32 (1936).—The nature of clays used for the production of these brick is of the highest importance. Clays which sinter well at low temperatures, such as Chasov-Yar clays, produce excellent grog brick. Clays which do not sinter satisfactorily at low temperatures, such as the Latninskiĭ type of clays, are unsatisfactory. The nature of grog and its granulometric composition are also important. Clays sintering well at low temperature yield high-grade grog. Samples containing from

15 to 20% of the so-called grog dust, *i.e.*, grog granules of less than 0.15 mm., were of high grade, while those without grog dust were of low mechanical strength.

M.V.C.

**Electrodinas.** I. S. SMELYANSKIĬ, L. V. DRAZHNIKOVA, AND S. LESNITSCHENKO. *Tech-SO*, **27** [303] 8 pp. (1936); reviewed in *Referat. Silikatliteratur*, **3**, 3478 (1936).—The new silica brick withstood 43 charges in the crown of an electric steel furnace. The resistance to firing of silica brick is affected by the properties of the raw materials and the amount of milk of lime added. The fusing point of pure quartzite is 1760°, and that of a silica brick with 2% lime is 1720 to 1730°C. Obviously, a low lime addition is desirable. Tests show, however, that (under similar conditions) the brick with less than 2% lime had a dull ring and cracks because the thickness of the lime film was inadequate. To obtain a sufficiently thick lime film with less than 2% lime, the total surface of the grains in the mix was lowered by using coarser grains (corrections for granulometric curves are given). In the new silica brick, the moisture content is 5.6 to 6.3% (old brick 6 to 6.8%); the lime content is 1.5%, and much better properties are obtained. M.V.C.

**Flaking of continuous vertical retorts.** A. T. GREEN AND F. H. CLEWS. *Refrac. Materials Joint Sub-Committee, Inst. Gas Engrs., 24th Rept.*, No. 78, pp. 79–92 (1933); *Chem. Abs.*, **29**, 6380 (1935).

**High-grade refractory materials.** Z. UNENO. *Jour. Fuel Soc. Japan*, **13**, 91–93 (1934); *Brit. Chem. Abs.-B*, **53** [47] 1011 (1934).—The manufacture and properties of Corhart electrocast aluminous, *e.g.*, 75%, refractories, which are highly resistant to corrosion by slags, glass, cement, and metals, are described. The main properties of Corhart Black (the electrocast product) and White (made by bonding the pulverized cast material) are, respectively, as follows: refractoriness, cone 38 (approximately 1850°), cone 36 (1795°); refractoriness under load (2 kg./sq. cm.), > 1740°, 1400 to 1560°; linear thermal expansion at 1000°, 0.53% for both; thermal conductivity [kg.-cal./sq. m./hr./°C (for 1-cm. thickness?)], 3.29 and 1.67 at 300°, 2.95 and 1.40 at 1300°; crushing strength 1000 to 1500, 350 to 750 kg./sq. cm.; porosity, 1, 10 to 20%; density 3.3 to 3.4, 3.0 to 3.2; hardness (Black) 42 (Martin's scale).

**Hot patching of gas retorts: II, Experiments on the use of dry powdered cements containing silicon and aluminum.** F. H. CLEWS, H. BOOTH, AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, Inst. Gas Engrs., 24th Rept.*, No. 78, pp. 7–19 (1933); *Chem. Abs.*, **29**, 6379 (1935).

**Insulating and high-temperature refractories.** ANON. *Metal Progress*, **26** [4] 77–80 (Oct., 1934); abstracted in *Bull. Brit. Non-Ferrous Metals Research Assn.*, No. 70, p. 25 (1934).—Progress in the production of refractories derived from clays and rocks, *e.g.*, insulating refractories, high-alumina refractories, refractory cements, and ramming mixes, is discussed.

**Jointing cements: I, Preliminary investigations.** A. T. GREEN AND H. N. ROY. *Refrac. Materials Joint Sub-Committee, Inst. Gas Engrs., 24th Rept.*, No. 78, pp. 57–67 (1933); *Chem. Abs.*, **29**, 6380 (1935).—The literature is reviewed. Physical and refractory properties of eight fireclay and four silica cements are given. The texture is related to the drying and firing shrinkages, tensile strength, and adhesion. There is some connection between the texture of a cement and its behavior in the under-load test. **II, Experiments on silica cements.** F. H. CLEWS, H. BOOTH, AND A. T. GREEN. *Refrac. Materials Joint Sub-Committee, Inst. Gas. Engrs., 24th Rept.*, No. 78, pp. 67–78 (1933); *Chem. Abs.*, **29**, 6380 (1935).—Refractoriness under light load for small contents of lime in lime-ganister mixtures is scarcely affected by the proportion of lime; slight contamination with other oxides modifies this conclusion. Ganister-lime cements had little adherence to the brick. Other results are more preliminary in nature.

**Method of determining permeability of refractory materials.** T. R. LYNAM AND W. J. REES. *Refrac. Materials Joint Sub-Committee, Inst. Gas Engrs., 24th Rept.*, No. 78, pp. 31–34 (1933); *Chem. Abs.*, **29**, 6380 (1935).

**Methods of avoiding cracks and bad structure in the production of refractories for blast furnaces.** V. STRELETZ. *Ogneupory*, **2** [10] 18–23 (1934); *Chem. Abs.*, **29** [15] 5239 (1935).—The following granulometric composition gave a good structure and improved the mechanical strength, water absorption, and volume porosity: grains of 0.6 mm. 60%, of 1 mm. 22 to 25%, and of 2 mm. 10 to 15%. An increased moisture content (to 16 to 17%) gave better results in pressing. See *Ceram. Abs.*, **14** [8] 189 (1935).

**Methods of high-temperature insulation.** T. BARRATT. *Steam Engr.*, **6**, 25 (1936); *Trans. Ceram. Soc.*, **35** [11] 93A (1936).—The fundamental principles of insulation of furnace walls, arches, and roofs, steel-reheating furnaces, glass tanks, and open-hearth furnaces are discussed.

**Properties and uses of mullite refractories.** M. L. FREED. *Ind. Heating*, **4** [1] 57–62 (1937).—Properties required of high-temperature refractories are discussed. A refractory for temperatures of 3000°F and higher, mullite, consisting of calcined sillimanite minerals (kyanite, andalusite, and sillimanite) is described. Fields of application as lining materials, in places where flames impinge, in high-frequency furnaces, and, in general, where refractories are subject to excessive spalling conditions and heavy loads at high temperatures are mentioned.

M.H.

**Refractories.** ANON. *Trade & Eng.*, **40** [875] xviii (1937).—A review of commercial practice and research during 1936 is given. Refractories in the British Isles are still sold more on "reputation" than on tests, but buyers are increasingly coöperating with manufacturers. No great changes in methods of manufacture were made in 1936, but the general increasing mechanization is noticeable. Super-refractories are slowly growing in popularity, and much interest has been shown in brick made of celsian (a barium anorthite) and in highly porous brick for thermal insulation. Plastic refractories or refractory cements are being increasingly used. A "standard ganister mixture" is now obtainable. Research is chiefly confined to changes in physical properties on heating. A serious effort is being made to place the financing of research on a sound foundation. A.B.S.

**Refractories for enameling muffle furnaces.** J. WALKER. *Foundry Trade Jour.*, **54** [1024] 265–68, 270 (1936).—The general requirements for refractories in-

clude (1) high refractoriness, (2) high strength, hot or cold, (3) volume stability at high temperatures, (4) resistance to slag attack, (5) resistance to rapid temperature changes and other thermal stresses, (6) low or high heat capacity, (7) low or high thermal conductivity, and (8) low or high electrical conductivity. In general, commercial refractories are compromises which meet a group of contradictory requirements fairly well. The ideal refractory for enamel muffles is analyzed from the standpoint of the above requirements, and the differences in coal-, gas-, and oil-fired and electrically heated furnaces are pointed out. **Discussion.** WHITTLE *et al.* *Ibid.*, [1029] 372, 374.

H.E.S.

**Refractories in the foundry and furnace.** W. HAMILTON. *Foundry Trade Jour.*, **54** [1015] 101 (1936).—Results obtained from practical experiences in the use of refractory materials in both foundry and furnace are given. In connection with molding sand, the refractory manufacturer has given the foundrymen valuable assistance in finding a suitable base sand and in blending, grading, and bonding. Monolithic cupola linings have made considerable progress and may be universally adopted in the future. The same is true of the steel converter, either Stock or Tropenas. The high-alumina refractory brick is being successfully used in foundry furnaces. A brick composed of chrome and magnesite of definite proportions to counteract some of the failings of the magnesite brick gives service at a considerably lower initial cost than the latter and is now being used successfully both in the electric and basic open-hearth furnaces. H.E.S.

**Refractories industry in 1935.** W. J. REES. *Foundry Trade Jour.*, **54** [1012] 32, 40 (1936).—The progress in the refractory industry for 1935 is briefly outlined. The dry pressing of refractories has increased, especially at higher pressures, with the manufacture of "unburned" magnesite refractories. Attention is being directed to the production of fused refractories, both by casting the fused material into special molds and by machine-pressing the crushed and graded prefused material. The use of de-airing machines and carefully controlled tunnel kiln firing of refractories are described. With silica brick for steel melting furnaces, the trend is toward the use of well-converted brick with a high tridymite content. There has been an extensive application of insulating brick. Basic refractories are being used for the roof and other parts of the basic open-hearth furnace. On the nonferrous side, increasing use is being made of sillimanite refractories. The increased publication of phase diagrams is of fundamental interest.

H.E.S.

**Refractory and acidproof ceramic products.** W. G. LINGBEEK. *Ingenieur*, **49**, Mk. 45–48 (1934); *Chem. Abs.*, **29**, 4910 (1935).—L. reviews particularly silica and fire clay with their temperature diagrams and characteristics.

**Refractory building materials. Testing methods (Poland).** ANON. *Wiadomosci Polskiego Komitetu Normalizacyjnego*, **11** [4] 40–43; [5–6] 67–68 (1936); abstracted in *Referat. Silikatliteratur*, **3** [11] 3438 (1936).—Refractory building materials, including (*a*) artificial, fired, (*b*) natural, neither fired nor worked, and (*c*) mortar and refractory masses, should have at least P.C.E. 26. A description of the following standard tests is given: (1) obtaining an average sample, (2) determination of refractoriness, (3) determination of specific gravity, volume weight, and porosity, (4) absorption of water and apparent porosity, (5) resistance to pressure, and (6) chemical analysis of clay, quartzite, grog, and silica products.

M.V.C.

**Refractory clays.** MUGNEROT. *Rev. Fonderie Moderne*, **30**, 335–40 (1936).—Refractory clays (the French pisés, not the usual "argile") are siliceous, preferably quartz, materials reduced to sand with a slight percentage of actual clay. They are often used simply tamped tightly and form an excellent lining material for furnaces, having, with 92 to 94% silica, a melting point of 1770°C; the softening point is very close to the melting point. When the clays are mixed with up to 6% alumina the melting point is lowered, but beyond this up to 9.2% alumina the melting point increases again and approaches 1790 to 1810°C. The material is used frequently for lining electric furnaces. The composition of the deposits found in France and Germany is described. Brick made from this material are rather expensive. M.H.

**Refractory products.** V. BODIN. *Usine*, **44** [16] 27 (1936).—Refractories are defined as products whose fusion temperature exceeds 1500°C; they are divided into those with a Si-Al base and those not belonging to this group. The first group embraces all products of Si, silica, and silica alumina, such as bauxite and sillimanite; the second group consists of products of silicon carbide, graphite, zirconium, chrome-iron, and magnesia. The properties of the groups are briefly described, and points important for the selection of a material for a given case are discussed. M.H.

**Relation of air change to cupola operation.** H. V. CRAWFORD. *Trans. Amer. Foundrymen's Assn.*, **7** [1] 303–12 (1936).—The reactions that take place in the cupola and the best operation of such a furnace are shown. The cupola is divided into zones, and the function of each is explained. C. also explains the reactions that should take place within each zone and how improper control of the air supply, coke, and iron charges influences the thermal efficiency and consequently the melting efficiency.

H.E.S.

**Relationship between durability in service and properties of refractory brick.** OTTO PHILIPP. *Ber. Deut. Keram. Ges.*, **17** [9] 413–37 (1936).—Extensive plant tests were conducted on a powdered coal-fired billet furnace to determine the amount of wear and tear on the refractories, and the brick used for this purpose were subjected to laboratory tests to determine their chemical and physical properties. The practical tests in the combustion chamber of the billet furnace revealed that the refractories were subject to considerable wear and tear, the most favorable case showing a 34.7% loss in volume after 669 hours of service. The laboratory investigation showed that this rapid failure is due mainly to the inability of all the fireclay material to withstand long periods at the maximum temperature (1500°). Slag attack is of minor importance. The frequent changes of temperature proved detrimental to silica material. The brick tested also showed insufficient refractoriness-under-load strength for the working temperatures of the furnace. Special importance is attached to the determination of the inside wall temperature and the

load imposed on the brickwork in making a selection of refractory material. Illustrated. E.J.V.

**Silicon carbide from Migiurtinia, Somaliland.** P. ALOISI. *Periodico Mineral.*, **5**, 191–92 (1934); *Neues Jahrb. Mineral. Geol. A*, p. 39 (1935); *Chem. Abs.*, **29**, 5777 (1935).—Crystals of SiC are described. It is unknown whether they occur naturally or whether they are a metallurgical product.

**Ural kyanite, conditions of its mullitization, and technology of the production of mullite ware.** P. S. MAMUIKIN. *Trudy Vsesoyuz. Mendeleev. S'ezda, 1932*, **2** [1] 459–60 (1935); *Chem. Abs.*, **29**, 7600 (1935).

**Working up bauxite by means of sulfurous acid to produce alumina.** LÁSZLÓ PUTNOKY AND BÉLA BOBEST. *Math. Naturw. Anz. Ungar. Akad. Wiss.*, **52**, 86–132 (1935); *Chem. Abs.*, **29**, 6371 (1935).—Experiments were made with seven samples of Hungarian bauxite ores containing $Al_2O_3$ 43.12 to 62.10, $Fe_2O_3$ 9.51 to 28.08, $TiO_2$ 2.50 to 4.39, $SiO_2$ 2.86 to 8.10, and loss on ignition 18.82 to 29.70%, respectively. Ores were treated under pressure in steel bombs with saturated $SO_2$ solutions in the presence of excess $SO_2$ at 20 to 120° from 1 to 10 hr. The $SO_2$ used varied from 9 to 66% of the mixture of bauxite and water. The results were unsatisfactory. $Al_2O_3$ concentration of the solutions was in all cases under 2%, and only 40 to 70% of the total alum content of the ores was soluble. The Fe content of ores, however, was 95% dissolved. The poor solubility was due to the fact that the Al of bauxite ores consists partly of very difficultly soluble compounds, and hydrolysis takes place in Al sulfite solutions, the product of which, $AlOHSO_3 \cdot 2H_2O$, is slightly soluble. The amount of this product increased with the temperature. $TiO_2$ and $SiO_2$ were also dissolved by $SO_2$ and contaminated the $Al_2O_3$ since they precipitated simultaneously with $Al_2O_3$.

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**Checker brickwork construction for regenerators.** J. F. HYSLOP (John G. Stein & Co., Ltd.). U. S. 2,068,292, Jan. 19, 1937 (Aug. 19, 1936).

**Furnace construction.** HERBERT HEITMAN. U. S. 2,071,069, Feb. 16, 1937 (April 5, 1934). A furnace construction comprises an outer wall of brick and an inner wall of interlocked refractory tile constructed and arranged for relative movement and to oppose the transfer of heat, a course of header brick fast in the outer wall and loose in the inner wall to oppose heat transfer, there being spaces underlying the header brick to permit movement of the inner wall and to support the upper portions of the latter when portions of the inner wall rest on the upper faces of the header brick, and hinged through-bolts connecting the walls substantially as described.

**Furnace for heating materials under sustained pressure.** P. R. CHURCH AND H. C. RATEAU. U. S. 2,070,983, Feb. 16, 1937 (April 2, 1936).

**Furnace-wall construction.** MARTIN FRISCH (Foster Wheeler Corp.). U. S. 2,070,267, Feb. 9, 1937 (April 24, 1931).

**High-pressure nonplastic refractory and method of making.** R. P. HEUER (General Refractories Co.). U. S. 2,068,411, Jan. 19, 1937 (Jan. 9, 1934). The method of making a refractory of high density from anhydrous nonplastic material and a bonding substance using anhydrous nonplastic particles of relatively larger and smaller grain sizes consists in mixing larger anhydrous nonplastic particles retained on a 30-mesh per linear inch screen with smaller anhydrous nonplastic particles and a bonding substance while employing not more than a relatively small proportion of intermediate anhydrous nonplastic particles, in molding the mix in moist condition into a refractory shape, in drying the refractory shape, and in subjecting the dried unfired refractory shape to firing temperature in a furnace structure during use.

**Sectionally supported wall.** H. A. MANNSHARDT (American Arch Co., Inc.). U. S. 2,068,863, Jan. 26, 1937 (Aug. 1, 1931).

**Spalling resistant refractory brick.** G. M. CARRIE, J. W. CRAIG, F. E. LATHE, AND A. C. HALFERDAHL. U. S. 2,068,641, Jan. 26, 1937 (July 16, 1931). A spalling-resistant, refractory, and chemically neutral fired brick containing 15 to 50% of chrome iron ore and 50 to 85% of a dead-burned magnesian clinker which contains 10 to 25% of lime, and consisting of coarse and fine particles of which the chrome iron ore is the coarse constituent.

## Terra Cotta

**Manufacture of salt-glazed stoneware pipes and fittings.** A. COULHON. *Brit. Clayworker*, **45** [537] 307–309 (1937).—Various types of kilns used in this industry are discussed with special reference to intermittent kilns. A round downdraft kiln and a rectangular downdraft kiln are described. See *Ceram. Abs.*, **16** [3] 96 (1937). R.A.H.

**Method for determining acid-stable natural rocks, ceramic ware, and bodies for chemical apparatus.** L. W. MURAVLEV. *Trudy Vsesoyuz. Mendeleev. S'ezda, VI Congr.*, **2** (Part I), 313–14 (1935); abstracted in *Chem. Zentr.*, **1936, ii**, 2972–73.—The ground and sifted material is washed with distilled water and dried; 1 kg. of the sample is treated with 25 cc. C.P. $H_2SO_4$, boiled, cooled, diluted with distilled water, and filtered. The residue is washed with hot water and treated with 20 cc. hot water and 5 cc. $NH_4Cl$ solution (5%); Cl is washed off. The dried and calcined residue yields acid stability. M.V.C.

**Production of engobe tile.** E. BERDEL. *Ber. Deut. Keram. Ges.*, **16** [12] 611–16 (1935).—A series of experiments carried out to discover a glaze for use on slip or engobe-coated tile which would have a low firing temperature and a low expansion coefficient and be free from crazing, colorless, and high in resistance to cracking is described in detail. Various bodies were used in making the tests, and their effect on the glazes is noted. E.J.V.

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**Apparatus for applying glaze, etc., to tile.** W. BOULTON, LTD., AND H. H. HALL. Brit. 459,552, Jan. 20, 1937 (Aug. 17, 1935).

**Insulating material having a high dielectric constant and a process of producing.** WERNER SOYCK AND ALFRED UNGEWISS. U. S. 2,069,903, Feb. 9, 1937 (Dec. 27, 1935).

## Whiteware

**Effect of composition on properties of household porcelain.** A. N. EGOROV. *Keram. & Steklo*, **12** [11] 25–29 (1936).—The composition of bodies and their testing, with regard to resistance to rupture, impact strength, translucence of body, and deformation on firing, are discussed in detail. Results are tabulated. See "Influence—" *Ceram. Abs.*, **14** [5] 121 (1935). M.V.C.

**Effect of replacing dolomitic lime by baryta upon some properties of glass.** VINCENT E. WESSELS. *Jour. Amer. Ceram. Soc.*, **20** [3] 79–84 (1937).

**Heat conductivity of electrical conductors.** A. S. PREDVODITELEV. *Zhur. Eksp. Teoret. Fiz.*, **4**, 838–54 (1934); *Chem. Abs.*, **29**, 7780 (1935).—On the basis of modern conceptions of the nature of matter, a theory is developed and compared with data for a large number of metals.

**Heat conductivity of solid heat insulators.** A. S. PREDVODITELEV. *Zhur. Eksp. Teoret. Fiz.*, **4**, 813–37 (1934); *Chem. Abs.*, **29**, 7780 (1935).—On the basis of considerations as to acoustic waves in isotropic solids, a theory of heat conductivity is developed and compared with experimental data on NaCl, KCl, $CaF_2$, $NaClO_3$, $SiO_2$, glass, $CaCO_3$ as marble and as calcite, ice, carbon steel, constantan, manganin, Bi, brass, Sb, chrome-nickel steel, and German silver.

**Nature of glass in a porcelain body.** SEIJI KONDO AND KESAKICHI MOTE. *Jour. Japan. Ceram. Assn.*, **41**, 453–68 (1933); *Jour. Soc. Glass Tech.*, **18** [69] 5A (1934).—Results of optical measurements for forty-three porcelain bodies made of kaolin, feldspar, and quartz or kaolin, feldspar, and alumina are given. Each material was ground to pass through a sieve of 10,000 meshes/sq. cm. The members in the systems kaolin–feldspar–quartz and kaolin–feldspar–alumina were compounded and formed into small cones. After firing to 1460° and preparing thin sections, their microstructures were observed. Thin sections of the system kaolin–feldspar–quartz consisted of glass, quartz, mullite, yellow spots, and pore, while those of the system kaolin–feldspar–alumina contained crystalline alumina in addition. The glasses were heterogeneous even in the same thin section. Solubility of mullite in the glasses is discussed. Their refractive indices were determined by the double variation method originated by R. C. Emmons (*Ceram. Abs.*, **8** [1] 70–71 (1929); **9** [2] 134; [3] 217 (1930); **11** [8] 468 (1932)) and improved by T. Sueno. The relation between the refractive index and the chemical composition is shown by tables and triaxial diagrams. The general tendency is that quartz reduces the index, while alumina and kaolin increase it. See *ibid.*, **12** [10–11] 382 (1933).

**Porcelain sheaths for thermocouples.** V. TARANENKO. *Zavodskaya Lab.*, **3**, 1038 (1934).—A porcelain plate is fused to the end of a porcelain tube with an arc (10 to 15 amperes). Hot pulverized borax and clean sand are applied and the tube is heated once more. P.B. & E.S.

**Properties of newly discovered "pottery" materials and their uses.** SHINICHIRO OGAWA AND KOJI TERAZAKI. *Repts. Imp. Fuel Research Inst. Japan*, No. 17, pp. 1–36 (1936); abstracted in *Chem. Zentr.*, **1936**, ii, 3166.—Three kinds of pottery materials recently discovered were studied. They represent weathering materials of liparite, quartz porphyry, and andesite which are the most important and characteristic raw materials of Japanese porcelain. Among the materials used, Amakusa rock is the most suitable and has been used for the last 200 years. The properties of the new materials were compared with those of the Amakusa material. The resistance to pressure, density, volume true porosity, chemical disintegration, P.C.E., mineralogical composition, plasticity, and shrinkage on drying and firing were determined. Daido rock (Korea) can be used for the manufacture of feldspar-like earthenware and semiporcelain. Banke rock is suitable for the Japanese porcelain-like and dolomite earthenware, and Tsukuda rock is suitable for white or ivory porcelain fired at a low temperature. The chemical and mineralogical composition of these materials is tabulated. See "Quality—" *Ceram. Abs.*, **16** [3] 98 (1937). M.V.C.

### PATENTS

**Alkali-free ceramic materials and method of making.** A. H. FESSLER (General Motors Corp.). U. S. 2,069,060, Jan. 26, 1937 (Dec. 14, 1935). The method of producing ceramic materials substantially free of alkali consists in adding boric acid to ceramic material containing alkaline impurities and heat treating the material to an extent to volatilize the boric acid and with it the major portion of the alkali.

**Bathtub.** I. B. GARDINER. U. S. 2,070,120, Feb. 9, 1937 (March 4, 1936). A bathtub has in the bottom thereof a raised portion extending from substantially one end of the tub to a point materially inwardly from the relatively opposite end of the tub, the raised portion having a recess in the top face thereof, a mat fitting snugly within the recess, and a rib projecting upwardly from the raised bottom of the tub and provided intermediate its end with a drain slot.

**Earthenware body.** I. E. SPROAT (R. T. Vanderbilt Co., Inc.). U. S. 2,068,154, Jan. 19, 1937 (Oct. 30, 1935). Glazed, semivitreous, earthenware bodies having a bisque made from a mixture comprising clay from the class consisting of ball clays, kaolins, and china clay, and pyrophyllite, both in substantial amount, and a small percentage of a calcium compound sufficient to impart decreased moisture expansion in the resulting body, the amount of calcium compound being greater than that occurring naturally in the pyrophyllite and clay and between about 0.5 and 5%.

**Method of producing ceramic ware.** A. H. FESSLER (General Motors Corp.). U. S. 2,069,059, Jan. 26, 1937 (Aug. 23, 1934).

**Process and apparatus for manufacturing insulators.** F. G. BOVARD (Ohio Brass Co.). U. S. 2,068,941, Jan. 26, 1937 (Aug. 29, 1934). The method of forming a threaded opening in plastic material comprises the steps of first forming an unthreaded opening in the material and then feeding a threading die into the unthreaded opening, maintaining the outer surface of the threading die in contact with the inner surface of the opening entirely around the periphery of the opening during the feeding operation, and thus substantially preventing escape of air between the

outer surface of the threading die and the inner surface of the opening, pressing the material of the wall of the opening into thread formation by means of the die, and venting the opening to atmosphere through the threading die during the entrance and removal of the die.

**Soap dish for sinks.** W. C. GROENIGER (John B. Pierce Foundation). U. S. 2,070,010, Feb. 9, 1937 (Sept. 14, 1935).

**Tank flush valve—ball type.** W. C. GROENIGER (John B. Pierce Foundation). U. S. 2,068,672, Jan. 26, 1937 (July 5, 1935).

## Equipment and Apparatus

**Abrasives mask.** W. P. BIGGS. *Eng. Mining Jour.*, 137 [12] 644 (1936).—The mask described was developed by the Navy Department for the prevention of silicosis. A latex-covered silk hood fits over the head and shoulders of the operator, leaving exposed only the lens section of the face piece. Air is fed into the face piece through a corrugated rubber tube and passes out through double exhalation valves with extremely low resistance to air flow. The mask has a flow-control valve and can also be instantly detached from the air line so that the operator can breathe through a filter in the free end of the corrugated tube. Illustrated. J.L.G.

**Apparatus for measurement of shrinkage coefficient of soils.** B. N. SINGH AND P. B. MATHUR. *Soil Sci.*, 43 [1] 37–41 (1936).—A simple apparatus for measuring the shrinkage coefficient of soils is described. A few data on the shrinkage coefficient and the relative moisture capacities of a number of soils are presented. G.R.S.

**Apparatus for sampling gases at a constant rate.** A. BLACKIE. *Jour. Soc. Chem. Ind.*, 55 [42] 307–308 (1936).—B. describes a simple device by means of which a gas sample can be taken from a moving stream of gas at a constant rate over a period of time. The theory and method of operation are given. Tests have shown that the rate of collection of sample remains constant throughout the whole sampling period. Illustrated. G.R.S.

**Classification of drying, including graphical analysis of air drying as developed abroad.** A. WEISSELBERG, CHARLES W. THOMAS, AND T. R. OLIVE. *Trans. Amer. Soc. Mech. Engrs.*, 57, 41–47 (1935).—Drying is defined as the removal of evaporable liquids by the use of heat as contrasted with dehydration by mechanical means. Terms applying to drying are described. Formulas and curves are derived for the determination of the rate of drying and the heat required. The effect of diffusion of the liquid through the solid is considered. S.S.

**De-airing in an ordinary pug mill.** KENNETH SETTINIUS. *Jour. Amer. Ceram. Soc.*, 20 [3] 87–89 (1937).

**Determination of coal grindability by the ball-mill method.** C. G. BLACK. *Amer. Inst. Mining Met. Engrs. Contrib.*, No. 95, 23 pp. (1936); *Brit. Chem. Abs.–B*, 55 [21] 432 (1936).—A critical examination is made of the A.S.T.M. Tentative Standard ball-mill method in which the grindability is determined by the number of revolutions of the mill required to reduce 80% of the feed (500 g. of 10 to 20-mesh coal) to pass 200-mesh. Tests made with a wide variety of coals indicate that in order to get the true grindability of materials of differing density, it is necessary to grind to the same surface area. It is suggested that the method be modified by taking constant original volumes and grinding until 80 wt. % passes 200-mesh. The manner of preparing samples and the possibility of introducing mechanical screening and of reducing the test time required are also discussed. It is concluded that one method only should be chosen as a standard because the results obtained by the ball-mill and the Hardgrove-machine methods, now tentative standards, are not comparable.

**Developments in the battle against corrosion.** V. A. ROHLIN AND C. E. JOOS. *Combustion*, 8 [1] 22–26 (1936).—The authors discuss the principles and problems involved in the mechanical de-airing of boiler feedwater to meet the exacting demands of present practice and describe two late types of de-airing heaters. One is the tray type in which the flow of water and steam are parallel; the other employs the counterflow principle and operates by spraying and atomizing without the use of trays. H.E.S.

**Dial thermometers.** AMERICAN SCHAEFFER & BUDENBERG DIV., CONSOLIDATED ASHCROFT HANCOCK CO., INC. *Instruments*, 10 [1] 6 (1937).—This is said to be the only dial thermometer with all parts made of corrosion-resistant material (stainless steel). The moisture- and dust-proof case is made of a phenol condensate and has a shatter-proof front. The thermometer may be used for temperatures from −40 to 1000°F and at distances up to 1000 ft. The thermal system is mercury filled. R.W.R.

**Electromagnetic separators, with special consideration of the ceramic industry.** G. S. ULLRICH. *Ber. Deut. Keram. Ges.*, 16 [5] 243–52 (1935).—Modern electromagnetic separators which can be used in the ceramic industries to remove iron and iron-bearing silicates from both raw materials and ceramic bodies are described in detail. These range from the simple electromagnet, over which the material flows, to complicated machines. Illustrated. E.J.V.

**Experimental investigation of radiation heat exchange in combustion chambers.** M. STYRIKOWITSCH. *Tech. Phys. U.S.S.R.*, 3 [3] 197–208 (1936); abstracted in *Physik. Ber.*, 17 [20] 1859 (1936).—While determining the distribution of radiation in a combustion chamber it was observed that the lenses used in radiation pyrometers are transparent for only part of the spectrum. For industrial conditions, only metal reflectors or fluorspar lenses should be employed which transmit the waves from 0.5 to about 10$\mu$ occurring in flame spectra. Measuring methods are described in detail. M.H.

**Gas-tight furnace for thermocouple standardization.** D. C. NEVIN. *Can. Jour. Research*, 14A [9] 177–80 (1936).—A detailed description of a redesigned gas-tight furnace for calibrating Pt-PtRh standard thermocouples in molten metals is given. E.J.V.

**Hardness and hardness measurements: I.** S. R. WILLIAMS. *Instruments*, 10 [1] 12–14 (1937).—Fields in which hardness measurements are particularly important are discussed. R.W.R.

**Heat-enduring alloys aid in casting huge telescopic disk.**

R. STUART BROWN. *Ind. Heating*, **4** [1] 37–38 (1937).—Cores in the glass mold were held in place by anchors of calite alloy (26% Cr, 10% Ni alloy) which withstood the temperatures without burning through as had other core holders. M.H.

**Heat-resisting alloys.** J. F. KAYSER. *Foundry Trade Jour.*, **54** [1011] 10–12 (1936).—To be able to judge whether or not a heat-resisting metal may be economically applied for a particular purpose, it is necessary to thoroughly appreciate the nature of the conditions under which the metal will have to work. The real strength of the metal must be known as well as the strength at elevated temperatures. Various types of heat-resisting alloys, such as Ni-Cr-Fe, Fe-Al, Fe-Si, and Cr-Al-Fe, are discussed. Surface protection by spraying, calorizing, and plating is considered. A discussion is included. H.E.S.

**Hood respirator.** DE VILBISS CO. *Ind. Finishing*, **13** [2] 58 (1936).—The respirator covers the entire head and neck to give complete protection against materials present in the air which are harmful to eyes, ears, or respiratory organs. Air flows into the hood through a filter, diffuses throughout, and flows out through the opening provided for vision. The hood fastens around the neck with a draw string. Illustrated. J.L.G.

**Humidity control device for ovens.** C. T. WEBSTER. *Jour. Sci. Instruments*, **13** [12] 412–13 (1936).—W. employs the principle of the wet- and dry-bulb thermometer to control the humidity in an electric oven. The arrangement described can be used to maintain the humidity at any desired value between 25 and 90% within ±1% over a range of temperatures. Illustrated. J.L.G.

**Improved motion-study camera and projector.** PRODUCTION CONTROL MACHINES CORP. *Instruments*, **10** [1] 8 (1937).—A new camera with a stronger motor and additional adjustments and a new projector with a larger lamp are now available. The apparatus uses 8-mm. film, available in 25- and 100-ft. rolls. R.W.R.

**Laws of drying of solid bodies.** C. C. *Argile*, No. 165, p. 13 (1936).—The forces which produce the phenomenon of drying are diffusion and capillarity. Drying is discussed in regard to (1) velocity of constant drying, (2) phase in which the pressure of the humidity coming from within diminishes until the water of the surface layers is entirely extracted, and (3) internal resistances. Reference is made to the researches of Sherwood (*Brit. Ind. Rev.*, 1929; *Ceram. Abs.*, **9** [7] 588 (1930)) and Kroell (*Bull. Assn. German Engrs.*, Aug. 8, 1936). M.V.C.

**Magnetic detectors for industrial applications.** R. F. EDGAR. *Gen. Elec. Rev.*, **39** [11] 559–62 (1936).—Various types of magnetic detectors for the inspection of nonmetallic materials, the magnetic analysis of nonmagnetic materials, and assurance of the presence of essential concealed iron are described. Illustrated. L.E.T.

**Magnetic separators to deferrize quartz sand.** S. V. RODIN. *Keram. & Steklo*, **12** [10] 15 (1936).—A brief discussion of a magnetic separator for extracting weakly magnetic minerals during deferrization of quartz sand is given. M.V.C.

**Measuring dust.** S. C. BLACKTIN. *Discovery*, **17** [203] 347–50 (1936).—Instruments described for the study and measurement of dust are the konimeter, jet dust counter, thermal precipitator, settlement counter, and electrotor meter. H.H.S.

**Mechanical power transmission.** G. A. VAN BRUNT. *Factory Management & Maintenance*, **94** [11] S321–32 (1936).—The subjects considered are (1) group and individual systems, (2) laying out group drives, (3) use of unit drives, (4) speed reduction, and (5) obtaining variable speeds. Five tables, 14 photographs. J.L.G.

**Method of testing the mechanical resistance of glazes.** E. KIEFFER AND E. WETTIG. *Ber. Deut. Keram. Ges.*, **17** [8] 387–91 (1936).—A new apparatus constructed from the mechanism of an electric gramophone is described. The test piece, a circular disk of glazed porcelain 80 to 100 mm. in diameter, is fixed firmly to the turntable. A box having a number of holes bored through it is held between two brass rods, above the test piece. Closely fitting copper rods are passed through the holes in the box, and their lower ends rest on the test piece. By means of brass casings fitted to the top of the copper abrading rods it is possible to maintain a constant weight merely by introducing small shot into the casings. The ends of the rods resting on the glaze must be carefully rounded off and smoothed with sandpaper before each test. The weight of each rod with the brass casing and shot in it was exactly 40 g. The r.p.m. of the motor should not exceed 100. For each test the test piece was smeared with a mixture of corundum and glycerine, and the test lasted exactly 15 min. A determination of the loss in weight by abrasion for a number of materials was found to be as follows: German hard porcelain, 14 to 18 mg.; American chinaware, 20 to 25 mg.; earthenware (hard and soft of various makes) 27 to 45 mg. Illustrated. E.J.V.

**Methods of testing thermocouples and thermocouple materials.** W. F. ROESER AND H. T. WENSEL. *Jour. Research Nat. Bur. Standards*, **14** [3] 247–82 (1935); R.P.768. Price 5¢.—Methods used for testing thermocouples and thermocouple materials are described, and the precautions which must be observed to attain various degrees of accuracy are given. Methods developed and used at the National Bureau of Standards are described in detail. Guidance is given in selecting the method which is best adapted to a given set of conditions. R.A.H.

**Multiple grinding of thin-section chips.** CHESTER K. WENTWORTH AND FRANCIS T. SUZAKI. *Amer. Jour. Sci.*, **31**, 93–96 (1936).—An apparatus which will grind 20 to 25 rock chips at one time is described. It reduces the chips to 0.5-mm. thickness in preparation for the grinding of a thin section. J.B.A.

**New spectrophotometer and some of its applications.** J. L. MICHAELSON AND H. A. LIEBHAFSKY. *Gen. Elec. Rev.*, **39** [9] 445–50 (1936).—The spectrophotometer consists essentially of a double-prism monochrometer, a photoelectric photometer, and a graphical recorder. The features of the construction and advantages of the design are outlined. A discussion of its application in fields of industrial control, color specification, analysis, and research is given. Illustrated. L.E.T.

**Portable gas-analysis recorders.** PERMUTIT CO. *Instruments*, **10** [1] 7 (1937).—New portable "Ranarex" gas analyzers employing the specific-weight principle may be operated on lighting circuits or standard 6-volt automobile batteries. These instruments may be used for de-

termining the carbon dioxide content of boiler flue gases or furnace atmospheres, air-fuel ratio of internal-combustion engine exhaust gases, and specific gravity of manufactured or natural gases. In the model for internal-combustion engines a pressure and vacuum gage is built into the apparatus. R.W.R.

**Preparation of ceramic raw materials with a Granigg auger separator.** GÄBLER. *Ber. Deut. Keram. Ges.*, **16** [8] 420–31 (1935).—G. describes the Granigg separator, in which the auger is magnetized and serves to remove the iron and iron-bearing minerals from the raw material being ground. Specific instances of its application in actual practice, *e.g.*, in the separation of feldspar from granite, are given. Illustrated. E.J.V.

**Preparation of kaolin, chalk, etc., by centrifuging.** H. MADEL. *Ber. Deut. Keram. Ges.*, **16** [5] 240–43 (1935).—M. discusses the use of the centrifuge for separating kaolin from its associated minerals due to the difference in specific gravity of the various materials. He discusses the principle of the process in detail, using different makes of centrifuges for illustrating the various points. E.J.V.

**Pressure losses for fluid flow in curved pipes.** GARRIS H. KEULEGAN AND K. HILDING BEIJ. *Jour. Research Nat. Bur. Standards*, **18** [1] 89–114 (1937); R.P.965. Price 10¢.—Results are given of a study of the flow of water in smooth-walled, large-radius pipes for the viscous and turbulent régimes over a range of Reynolds numbers from 500 to 60,000. The discussion is based on data obtained with $^3/_8$-in. brass tubing. R.A.H.

**Simple method of obtaining fine hair lines for use with telescope or microscope.** J. R. HAYNES. *Rev. Sci. Instruments*, **7** [3] 156 (1936).—Fine straight fibers for use as hair lines or scale markings in a telescope or microscope may be easily obtained by drawing a small globule of rubber cement at the point of a pin. If permanence is desired, the fibers should be reinforced with glass. This is done by selecting the endpoints on a glass plate so that the fibers will lie wholly on the surface of the glass. The hair lines may be erased from the glass by means of a bit of cotton moistened in carbon tetrachloride. H.E.S.

**Standard tables for chromel-alumel thermocouples.** W. F. ROESER, A. I. DAHL, AND G. J. GOWENS. *Jour. Research Nat. Bur. Standards*, **14** [3] 239–46 (1935); R.P.767. Price 5¢.—Tables have been prepared giving the thermal e.m.f. of chromel P *vs.* alumel, chromel P *vs.* platinum, and alumel *vs.* platinum at various temperatures in the range −310 to 2500°F. The values in the range 0 to 2500°F are based on the calibration of 15 representative No. 8 gage chromel-alumel thermocouples selected after preliminary tests on 50 heats of each alloy made by the method regularly used. The tables give the temperature-e.m.f. relation of the thermocouples now manufactured as closely as the wires can be reproduced at the present time. The guarantee limits have been fixed by the manufacturer at ±5°F in the range 0 to 660°F and ±$^3/_4$% in the range 660 to 2300°F. The methods used in calibrating the thermocouples in the various temperature ranges are briefly described. R.A.H.

**Theory of drying.** OTTO TH. KORITNIG. *Deut. Wollen-Gewerbe*, **66**, 505–507 (1934); *Chem. Abs.*, **29**, 7704 (1935).—Factors involved in all cases of industrial drying which influence the amount of heat necessary for the drying chamber are (1) total heat of the saturated steam, (2) raising the saturated steam to the temperature of the heating gases, (3) amount of heat required to heat the material, (4) amount of heat necessary to raise the drying chamber and walls to the drying temperature, and (5) amount of heat which must be added to compensate for nonpreventable losses due to conduction, radiation, convection, and waste gases. For all technical heat calculations of air-drying installations it is necessary to take the physical laws for moist air as the basis, with the specific heats of air and steam constant. The warm air can pass through the drying room either naturally or by means of an exhaust or a blower. The warm-air velocity and drying time must be carefully determined. For economic reasons it is also advisable to measure daily the steam consumption and to compare it with the water converted into steam.

**Thermal expansion of cemented tungsten carbide.** PETER HIDNERT. *Jour. Research Nat. Bur. Standards*, **18** [1] 47–52 (1937); R.P.960. Price 5¢.—H. gives data on the linear thermal expansion of tungsten carbide mixtures containing about 6 to 13% of cobalt. These products are known as Carboloy in the U. S. The average coefficient of expansion of cemented tungsten carbide containing 5.9% of cobalt increases from $4.4 \times 10^{-6}$ for the range between 20 and 60°C to $5.9 \times 10^{-6}$ for the range between 300 and 400°C. The average coefficients of expansion for samples containing from 12.9 to 13.2% of cobalt increase from $5.0 \times 10^{-6}$ for the range between 20 and 60°C to $6.7 \times 10^{-6}$ for the range between 300 and 400°C. The rates increase linearly with temperature. R.A.H.

**Thermionic relay circuit for a.-c. or d.-c. supply for use with a thermoregulator.** P. L. TEMPLE. *Jour. Sci. Instruments*, **13** [12] 414–15 (1936).—An improved form of vacuum tube relay is described for control of a thermoregulator or any other type of switch which passes only a very small current. Illustrated. J.L.G.

**Time-cycle controllers and metallic mercury switches.** ELECTRIC SWITCH CORP. *Instruments*, **10** [1] 5 (1937).—For controlling machine operations electrically by means of solenoids and magnets in definite timing sequence, two general types of time-cycle controllers using new metallic mercury switches have been designed. The controller operates one or two circuits at the rate of 15, 30, 45, or 60 makes and breaks per min. by means of a shaded pole a.-c. (or universal) motor operating a cam and rocker arm. The quickly operating metallic mercury switches are described. These operate on tipping through an angle of approximately 10° from the horizontal and are supplied in 5-, 10-, and 15-ampere capacities and in various types. R.W.R.

**True and apparent impact strength.** OTTO BARTSCH. *Ber. Deut. Keram. Ges.*, **17** [6] 281–95 (1936).—Impact strength values obtained by the usual methods can not be taken as a measure of the true resistance to impact since they contain, in addition to the energy required to break the test piece, a certain proportion of kinetic energy which is shown in the force with which the fragments of the specimen are thrown forward. The true impact strength is the amount of energy required to break the specimen only. A method for determining this directly is described. With fireclay bodies the true impact strength is only 25 to 40%

of the apparent impact strength. It is possible to calculate the true impact strength from the apparent impact strength values. The proportion of residual kinetic energy produced in determining the apparent impact strength by the usual methods depends mainly on the weight and partly on the shape of the test piece. It is therefore suggested that when reporting the impact strength values, the weight and shape of the test specimen should be clearly stated. E.J.V.

**Viscosimeter for ceramics.** NEUMANN. *Ber. Deut. Keram. Ges.*, **16** [8] 431–33 (1935).—A modified viscosimeter with an inverted cone-shaped bottom is described, and the method of using it is explained. Its operation is said to be more simple than that of instruments in common usage. Illustrated. E.J.V.

BULLETINS

**Mining and grinding methods and costs at the Dennison Sewer Pipe Co. clay mine, Dennison, Ohio.** E. J. LINTNER. *U. S. Bur. Mines Information Circ.*, No. 6921, 16 pp. Free. R.A.H.

**Mining and grinding methods and costs at the Evans Pipe Co. clay mine, Uhrichsville, Ohio.** E. J. LINTNER. *U. S. Bur. Mines Information Circ.*, No. 6929, 18 pp. Free. Clay mining, crushing, and grinding methods at typical operations in Tuscarawas County, Ohio, a clay center, are described. R.A.H.

**Suggested methods for the reduction of mine accidents from the viewpoint of the safety engineer.** E. H. DENNY. *U. S. Bur. Mines Information Circ.*, No. 6925, 6 pp. Free. D. summarizes various features of mine safety for the conscientious mine safety engineer. R.A.H.

**De-airing machines.** ANON. *Fate-Root-Heath Co. Bull.*, No. 14; abstracted in *Ceram. Age*, **27** [6] 178 (1936).—Characteristics of units and features of operation are given for de-airing equipment in the heavy clay products industry, including brick and building tile. F.G.H.

**Vacuum pottery pug mills.** ANON. *Fate-Root-Heath Co. Bull.*, No. 15; abstracted in *Ceram. Age*, **27** [6] 178 (1936).—Vacuum pottery pug mills of different types and sizes, with information regarding capacity, operation, and features, are described. F.G.H.

PATENTS

**Apparatus for applying color or glaze to tile.** W. BOULTON, LTD., AND H. H. HALL. Brit. 458,577, Jan. 7, 1937 (June 15, 1935).

**Apparatus for producing brick closed on five sides.** P. KOHN. Brit. 457,228, Dec. 9, 1936 (Oct. 12, 1935).

**Apparatus for separating materials.** C. A. WENDELL. U. S. 2,068,783, Jan. 26, 1937 (Sept. 29, 1932). The separating apparatus comprises an inclined material-separating screen maintained under tension, means for imparting low-amplitude high-frequency vibrations to the screen, means providing a plurality of separate compartments above the screen, and respective masses of filter particles in the compartments.

**Clay-cutting device.** ERNST FREY. U. S. 2,069,948, Feb. 9, 1937 (March 7, 1935). An automatic clay-cutting device comprises, in combination, clay-feeding means, a carriage, a plurality of cutters arranged for reciprocation at substantially right angles to the carriage, and automatically operative means for angularly displacing part of the cutters between two cutting operations in the direction of feed.

**Conditioning of freshly quarried clay.** BIRD MACHINE CO. Brit. 459,778, Jan. 27, 1937 (Jan. 18, 1935).

**Crushing machine.** O. C. GRUENDER (Nordberg Mfg. Co.). U. S. 2,070,270, Feb. 9, 1937 (Dec. 12, 1932). A gyratory crusher includes a crushing head, means for imparting a gyratory movement thereto, and a crushing bowl surrounding the head.

**Extrusion of moist, plastic bodies.** BIRD MACHINE CO. Brit. 459,777, Jan. 27, 1937 (Nov. 28, 1934).

**Machine for making brick, tile, etc.** W. JOHNSON & SONS (Leeds), LTD., A. BONFIELD, AND E. A. MANN. Brit. 458,107, Dec. 23, 1936 (June 13, 1935).

**Machine for shearing blocks from an extruded column of plastic material.** ERNST FREY. U. S. 2,069,947, Feb. 9, 1937 (March 7, 1935). An automatic machine for shearing blocks from a column of clay is described.

**Method and apparatus for producing porous lightweight aggregate from liquid slag.** E. B. BJORKMAN. Brit. 457,707, Dec. 16, 1936 (May 3, 1935).

**Method of coating surfaces.** H. V. SCHWEITZER AND D. A. CABLE (United States Quarry Tile Co.). U. S. 2,068,892, Jan. 26, 1937 (June 6, 1932). The method of applying fusible glazes, enamels, and similar coatings to earthenware, tile, metal, and other nonabsorbent materials consists in spraying a mixture of liquid and the fusible matter on the surface of the nonabsorbent material and directing a hot gaseous stream toward and intersecting the stream of the sprayed mixture after it has been sprayed but prior to its impingement on the surface to alter the consistency of the mixture, thereby to effect adherence of the mixture to the surface without further flow thereof.

**Method and means of collecting dust from an air current.** R. F. KNEISLEY (American Floor Surfacing Machine Co.). U. S. 2,068,332, Jan. 19, 1937 (June 24, 1936).

**Production of foamed slag from liquid slag.** E. B. BJORKMAN. Brit. 457,774, Dec. 16, 1936 (June 4, 1935).

**Purification of natural deposits.** R. W. FLINN. U. S. 2,070,161, Feb. 9, 1937 (Jan. 21, 1935). The method of purifying natural deposits in finely divided form in an oven comprises passing the material continuously through the oven, passing a continuous stream of chlorine gas through the oven, agitating the material during passage through the oven to obtain intimate mixture of gas and material particles, applying a heat gradient to the streams through the oven whereby different combinations of the gas and impurities in the oven will occur in different locations within the oven, and separately removing the different combinations.

## Kilns, Furnaces, Fuels, and Combustion

**Anthracite for firing ceramic ware.** YU. YU. BRUNSH. *Keram. & Steklo*, **12** [10] 22–25 (1936).—Directions for firing anthracite in ceramic furnaces are given. M.V.C.

**Experience with combustion control.** T. E. CROSSAN AND A. J. MATHERNE, JR. *Combustion*, **8** [1] 35–38 (1936).—The authors describe the combustion-control system installed to operate on natural gas and give operat-

ing experiences when the fuel averages 70% natural gas and the remainder petroleum coke breeze and acid sludge. Fuel oil is used when the natural gas supply is interrupted. H.E.S.

**Firing and cooling of yellow iron-stained clinker from a carbonaceous clay, and the changes in porosities and color occurring during the process.** E. TUSCHHOFF. *Ber. Deut. Keram. Ges.*, **17** [7] 333–53 (1936).—The raw material used in this investigation is found in Höganäs, Sweden. Due to its carbon content of 1 to 2%, a special firing schedule is necessary. Firing curves followed in a gas-fired chamber kiln are reproduced. By using the draw trial method and examining the specimens for porosity, the changes taking place in the body were followed through the entire firing treatment. To attain a desired color, a definite cooling time must be maintained in the range of 1300 to 1000°. The various effects caused by the iron in the clay, according to the different firing treatments, are described. Illustrated. E.J.V.

**Fuel meter for furnace combustion control.** S. F. BOWSER & CO. *Instruments*, **10** [1] 3 (1937).—A new furnace combustion control for heavy oils and tars uses a new Bowser "Registering Measure" for high-temperature service (50 to 250°F). This fluid meter is equipped with a 6-digit cyclometer for quantity metering and also drives a tachometric d.-c. generator. The $^3/_4$-in. size is recommended for flows not exceeding 8 to 10 gal./ min. and not less than 1 gal./min. Viscosity limits for metered fuels are 400 to 10,000 sec. Saybolt Universal. A steam jacket is available. Flow-rate indicators and recorders are standardized electric tachometric units calibrated in g.p.m. when operating from a standard generator. R.W.R.

**Fuel technology.** ANON. *Trade & Eng.*, **40** [875] xii (1937).—The newest methods for producing liquid fuel, colloidal fuel, oil, and motor spirit from coal are given with notes on trends in the treatment of coal for these purposes. A.B.S.

**Heat transfer in electric furnaces.** E. G. FIEGEHEN. *Engineer*, **156**, pp. 377–79 (Oct. 20, 1933); abstracted in *Jour. Iron & Steel Inst.* [London], **129** [1] 519 (1934).—F. discusses the approximate distribution of heat in electric resistor-type furnaces used for the annealing and heat treatment of steel castings. Such furnaces are generally run at about 1750°F, the maximum temperature desired in the castings being about 1650°F. The average oil-fired annealing furnace, without recuperation, has an overall efficiency of approximately 25% only, and of the total heat input about 50% escapes to the stack. As a result of the low efficiency, only 12 to 13% of the whole heat supplied goes to heat up the brickwork, and its rate of transfer becomes of minor importance. In the electric furnace there is no stack and the loss of heat in escaping gases is relatively small; consequently a much larger proportion of the heat input is absorbed by the brickwork.

**Hydrogenation.** F. S. SINNATT, J. G. KING, AND ANGUS MACFARLANE. *Ind. Eng. Chem.*, **29** [2] 133–40 (1937).—In 1923, experimental work on hydrogenation was started to ascertain whether British bituminous coals could be readily converted to gasoline. After a study of catalysts, an experimental plant of one ton per day capacity was constructed. The construction and operation of the semitechnical-scale tar hydrogenation plant now in use is described together with analyses of the raw and treated tars. Temperature conditions in the catalyst chamber and means for dissipating the heat of reaction are discussed. Illustrated. F.G.H.

**Mechanism of combustion of carbon particles under atmospheric pressure.** V. I. BLINOV. *Izvest. Vsesoyuz. Teplotekh. Inst.*, No. 7, pp. 8–17 (1934); *Chem. Abs.*, **29**, 4549 (1935).—The weight of a small graphite ball suspended in a furnace was checked at varying temperatures by means of a microbalance. At 700° the ball became heated up to the furnace temperature without changing its weight; above this temperature the weight began to decrease gradually. The weight decreased rapidly at 740 to 760°; this decrease was accompanied by a blue flame. The flame disappeared after a time and the temperature remained stationary during the combustion. Details of the experimental conditions are given and the results are calculated. 20 references.

**Oxidation of anthracite; liberation of carbon monoxide and its relation to ignition temperature.** G. S. SCOTT AND G. W. JONES. *Ind. Eng. Chem.*, **29** [1] 106–108 (1937).—A method and apparatus are described for obtaining the relative rates of liberation of carbon monoxide from carbonaceous substances during heating and for determining the ignition temperatures at the same time. The tests were designed primarily to identify quickly the most readily ignitible coals or other materials found in an anthracite mine. Special emphasis is placed on the rate at which carbon monoxide was liberated when the carbonaceous materials were heated at a constant rate in the presence of air. The initial temperature and rate at which carbon monoxide is liberated may have a direct or indirect relation to the tendency of carbonaceous materials to heat spontaneously. Illustrated. F.G.H.

**Possibility of calculating the heating value of a fuel from elementary analyses.** TORSTEN WIDELL. *Ivu*, pp. 57–64 (1935); *Chem. Abs.*, **29**, 6391 (1935).—Results obtained by the various known equations for calculating heating values from elementary analyses are compared graphically. Exact determination is impossible. There are wide divergencies.

**Sludge in heavy grades of fuel oil.** ANON. *Glass Ind.*, **17** [11] 377–78 (1936).—In adopting heavy grades of fuel oil for heating glass tanks, new operating difficulties have arisen, chiefly from the deposition of carbon or carbonaceous material formed when oils are subjected to excessive cracking. During storage the suspended particles flocculate and the sludge tends to settle out. This clogs feed lines and burners and causes difficulty in maintaining even combustion. Cracked residues also have high ash content. Sludge content and tendencies to form sludge should be checked before oil is purchased and before changing over from light oil to the Bunker "C" type. Methods of determining sludge are given. Particles of sludge falling on the glass give rise to blisters and seedy glass due to their slow oxidation. The high iron content of the ash often causes off-color glass in furnaces using cracked residue oils. A gravity settling system and filtration of the oil help to remove sludge, but the most practical and economical sludge-removing method is by use of the centrifuge. E.J.V.

BULLETIN

**Carbonizing properties and petrographic composition of Clintwood bed coal from Buchanan mines Nos. 1 and 2, Buchanan County, Va.** A. C. FIELDNER, J. D. DAVIS, R. THIESSEN, W. A. SELVIG, D. A. REYNOLDS, F. W. JUNG, AND G. C. SPRUNK. *U. S. Bur. Mines. Tech. Paper*, No. 570, 34 pp. Price 10¢. This is the 12th of a series of papers covering a survey of gas-, coke-, and by-product making properties of American coals being conducted by the Bureau in coöperation with the American Gas Assn. The yield and quality are given for products obtained at carbonizing temperatures of 500°, 600°, and 700°C, using a retort 13 in. in diameter, and at 800°, 900°, and 1000°C, using a retort 18 in. in diameter. Results of chemical, physical, and petrographic studies of the coal are also given. **Pittsburgh bed coal from Pittsburgh Terminal No. 9 mine, Washington County, Pa.** *Ibid.*, No. 571, 33 pp. Price 10¢. The yield and quality is given of products obtained at carbonizing temperatures of 500°, 600°, and 700°C, using charges of 85 lb., and at 800°, 900°, and 1000°C, using charges of 185 lb. Results of chemical, physical, and petrographic studies of the coal are also given. R.A.HEINDL

PATENT

**Electric furnace muffle construction.** T. H. FORDE (Diascope Corp., Ltd.). U. S. 2,002,241, May 21, 1935 (Oct. 30, 1931).

## Geology

**Accelerated weathering of feldspars.** F. H. NORTON. *Amer. Mineralogist*, **22** [1] 1–14 (1937).—A reaction chamber for carrying on the accelerated alteration of feldspars under constant temperature conditions has been developed. The reaction simulates natural conditions because fresh liquid is constantly supplied to the sample, and the soluble reaction products are constantly removed. Orthoclase was changed to sericite and anorthite to pyrophyllite under the particular conditions of the test, water and carbon dioxide being used as solution materials. The maximum temperature limits for these reactions were tentatively established as 350°C for orthoclase and 300°C for anorthite. Albite has been partially decomposed, but the end products have not been identified as yet. F.J.Z.

**Adsorption complex of mineral soils.** D. J. HISSINK, JAC. VAN DER SPEK, AND S. B. HOOGHOUDT. *Trans. Internat. Congr. Soil Sci., 3rd Congress, Oxford, 1935*, **1**, 82–84; *Chem. Abs.*, **29**, 7545 (1935).—Four clay soils were worked up as for mechanical analysis by the international method ($H_2O_2$–HCl–$NH_4OH$ + NaOH) and decanted with Atterberg cylinders to secure the fractions (*a*) 10 cm., 8 hr., less than 2$\mu$; (*b*) 10 cm., 30 min., 2 to 8$\mu$; (*c*) 10 cm., 7.5 min., 8 to 16$\mu$; the residue was sieved to secure (*d*) 16 to 43$\mu$. Suspensions of these fractions were electrodialyzed to remove all bases; it is noted that to prevent decomposition of the alumino-silicate complex during dialysis, humus must be absent. The dialyzed fractions were analyzed by $Na_2CO_3$ fusion and further examined by van Bemmelen's procedure for weathering silicates, (1) removed by 25% HCl followed by NaOH treatment and (2) removed from the residue by boiling with $H_2SO_4$ followed by NaOH treatment. Hissink's $T - S$ value was also determined from $Ba(OH)_2$ absorption; since $S = 0$, this gave $T$ directly. In (1), $x$ in the molecular ratio $Al_2O_3 \cdot xSiO_2 \cdot yH_2O$ decreased with increasing particle size; $y$ tended to decrease but was sometimes at a maximum in a coarser fraction. (*a*) contained around 90% of (1), (*b*) 6.9% maximum, (*c*) 2.8% maximum, and (*d*) 4.5% maximum. There was a striking parallelism between percentage of (1) in the fractions and $T$ values per 100 g., whence it is concluded that (1) dominates adsorption capacity. Similar experiments on kaolin and ground quartz fractionated to less than 2$\mu$ and electrodialyzed showed small values for $T$, proving that the adsorptive property is not dependent upon particle size alone but on specific chemical properties. The $T$ value of (1) from (*a*) fractions was 1.35 to 1.24 mg. equivalent /g., but lower values, down to 0.75, were obtained for other fractions. (1) of (*a*) is believed to be a Mg K Al silicate; (*b*), (*c*), and (*d*) are largely quartz. Determinations by the glass and quinhydrone electrodes showed that (*a*) was invariably very acid, $p_H$ 2.6 to 3.7 in 1:2.5 $H_2O$ suspension. Ultrafiltrates of these suspensions were approximately neutral, with one exception, $p_H$ 2.4; the addition of (*a*) to ultrafiltrate produced low $p_H$ values, indicating activity of solid particles as a souce of $H^+$. Further investigations are outlined.

**Adsorption of liquids by clays.** E. W. RUSSELL. *Trans. Internat. Congr. Soil Sci., 3rd Congress, Oxford, 1935*, **1**, 48–50; *Chem. Abs.*, **29**, 7551 (1935).—The factors on which the apparent density of clay in different liquids depends are analyzed. Clays are indicated to absorb nonpolar liquids weakly or not at all; the adsorption of polar liquids is due to the orientation of electric dipoles in their molecules in the electrostatic fields around exchangeable ions held by the clay and around the negative charges on the latter.

**Applicability of alkaline permanganate for oxidation of organic matter in soils for mechanical analysis.** J. N. CHAKRABORTY. *Soil Sci.*, **42** [4] 261–66 (1936).—A method of mechanical analysis using alkaline permanganate for oxidation of organic matter yields comparable results with the International-*A* method in the case of various Indian soils, *e.g.*, ordinary arable, forest, gypseous, peat, and lateritic soils. Thus the method appears to be a general one for mechanical analysis of soils. It is particularly suitable for soils rich in organic matter and is recommended for use in the tropics where hydrogen peroxide is not stable. Alkaline permanganate requires only a short time for oxidation of organic matter. Soils containing gypsum should be passed through a 70-mesh sieve after oxidation with alkaline permanganate and before addition of hydrochloric acid. 6 references. G.R.S.

**Associative and antagonistic effects of microörganisms: I, Historical review of antagonistic relationships.** SELMAN A. WAKSMAN. *Soil Sci.*, **43** ]1] 51–68 (1936).—A survey of the literature on the antagonistic relationships of microorganisms, with special reference to those that make up the

complex soil population, reveals certain important pertinent facts which are summarized as follows: Numerous organisms bring about injurious or destructive effects upon themselves or upon other soil organisms. In some cases, the injurious effect may be due to competition for nutrients; in other cases it is due to a change in the environmental conditions of the substrate, especially oxidation-reduction potential and reaction. More frequently it is due to the formation of substances which exert a definite toxic effect. The production of these toxic substances is greatly influenced by the reaction, temperature, and aëration of the substrate as well as the presence of other organisms. 107 references. **II, Antagonistic effects of microörganisms grown on artificial substrates.** SELMAN A. WAKSMAN AND J. W. FOSTER. *Ibid.*, pp. 69–76.—Different soil organisms found among the fungi, Actinomyces, and bacteria are capable of producing, when grown on synthetic media, substances which are antagonistic to the growth of other soil organisms. A detailed study was made of the antagonistic effect of one species of Actinomyces upon a variety of fungi, bacteria, and other Actinomyces. The inhibiting effect produced by this organism was shown not to be due to exhaustion of nutrients or to unfavorable changes in reaction, but to be specific in nature. The maximum production of the antagonistic substance took place in the cultures of the Actinomyces 7 to 18 days old. The substance was then gradually destroyed. Aëration and heat brought about rapid destruction of this substance. **III, Associative and antagonistic relationships in the decomposition of plant residues.** SELMAN A. WAKSMAN AND IMRI J. HUTCHINGS. *Ibid.*, pp. 77–92.—A study was made of the associative growth of the different fungi, Actinomyces, and bacteria upon different plant material and the resultant decomposition of the latter. It was found that the presence of one organism may modify considerably the growth of another. Different fungi were found to vary considerably in their ability to attack the various chemical constituents of plant residues and to exert varying influences upon the activities of other organisms as well as of the soil population as a whole. 13 references. G.R.S.

**Bauxitic clay of Najdziszów and the halloysite of Mierzecice, north of the Dabrowa basin, Poland.** JAN KUHL. *Arch. Minéral. Soc. Sci. Varsovie*, **9**, 105–15 (in French 114–15) (1933); *Chem. Abs.*, **29**, 7879 (1935).—The clays of Najdziszów, density 2.42, are of the bauxitic type and contain limonite, sericite, quartz, chalcedony, rutile, $Al_2O_3 \cdot 3H_2O$, and halloysite. Their composition is $SiO_2$ 34.69, $TiO_2$ 0, $Al_2O_3$ 42.03, $Fe_2O_3$ 0.27, CaO 0.16, MgO 0.15, $Na_2O$, $K_2O$ traces, and $H_2O$ (total) 22.84%. The clays of Mierzecice are of the halloysite type and contain sericite, quartz, chalcedony, limonite, rutile, and halloysite. Their composition is $SiO_2$ 40.42, $TiO_2$ 0.19, $Al_2O_3$ 34.07, $Fe_2O_3$ 0.63, CaO 0.62, MgO 0.32, $Na_2O$ 0, $K_2O$ 0.03, and $H_2O$ (total) 23.70%. Both clays are suitable for the production of fire-resistant clinker and cement and, owing to the readiness of separation of $Al(OH)_3$ with hot HCl, for the production of metallic Al.

**Behavior of polyvalent cations in base exchange.** J. E. GIESEKING AND HANS JENNY. *Soil Sci.*, **42** [4] 273–80 (1936).—A study was made to ascertain the rôle of monovalent and polyvalent cations in base-exchange reactions with Putnam clay. Although the behavior of the ions is irregular, it appears that the electric charges and the sizes of the ions are two of the major factors which determine the position of an ion in the adsorption and release series. G.R.S.

**Binding forces between clay particles in a soil crumb.** E. W. RUSSELL. *Trans. Internat. Congr. Soil Sci., 3rd Congress, Oxford, 1935*, **1**, 26–29; *Chem. Abs.*, **29**, 7551 (1935).—The hypothesis is advanced that clay particles are held together in a soil crumb by oriented molecules of a polar liquid; it is supported by experiments with various liquids as dispersion media. Only polar liquids produce hard crumbs. Exchangeable cations serve as the connection between clay particles in crumbs, linking the latter through their negative charges. The cation must also be small; large molecules of certain organic bases of high molecular weight produce only soft crumbs. See *Ceram. Abs.*, **14** [5] 124 (1935).

**Centrifuged and elutriated kaolin.** LAUBENHEIMER AND R. WAGNER. *Sprechsaal*, **69** [39] 563–64 (1936).—Comparison tests were made on samples of washed and centrifuged kaolins. The advantages of the Hertzsch centrifuge (Krupp-Grusonwerk, Magdeburg) over elutriating and its operation are explained. M.V.C.

**Ceramic investigations of concentrated Chasov-Yar ow-grade clays ("balyki").** A. I. KRAMARENKO AND SKIBINA. *Ogneupory*, **3** [5] 387–92 (1935).—A material with the same alumina content as the high-grade clays of this deposit and with a higher plasticity is obtained by concentration. P.B. & E.S.

**Chemical and physical changes in soil colloids with advancing development in Illinois soils.** R. H. BRAY. *Soil Sci.*, **43** [1] 1–14 (1936).—The study includes five profiles varying in profile development and weathered condition. Development took place under a humid temperate climate now characterized by warm summers and cold winters and by a rainfall of 36 to 40 in. The study of the physical changes of the colloids with advancing development was confined to the amount and distribution of the coarse, fine, and superfine size fractions. The development of horizons I and II is due to the formation and movement of very fine colloidal silicates (the beidellite-type materials). The chemical alteration of one mineral to form another need not necessarily involve a change in size of the altered particle. There is the possibility that the product formed by the alteration is more readily broken than the mineral being altered. Physical weathering of the colloid would, in such a case, effect a partial size separation of the altered from the unaltered forms. Subsequent fractionation of the whole colloid would then effect a separation, and the resulting size fractions would vary correspondingly in composition, compared with their composition before physical weathering occurred. The general tendency is for the $K_2O$, MgO, and $Fe_2O_3$ to decrease with advancing development and the $SiO_2$-$R_2O_3$ ratio to increase, in the case of coarse colloids. The $K_2O$ values are greatly reduced in the superfine fractions, while the MgO values are only slightly lower. The trend with respect to maturity, however, is the same for $K_2O$, MgO, and base-exchange capacity as that found in the coarse colloid. Iron, organic matter, and water are decidedly higher in corresponding superfine fractions. In contrast to the coarse colloid, the

$SiO_2$-$R_2O_3$ ratios decrease with advancing maturity. Data for the fine colloids are not included but are more nearly similar to the superfine values than to the coarse colloid values. G.R.S.

**Clays of Landes.** E.-S. GREIGOV. *Argile*, No. 165, p. 19 (1936).—The sources of the clays used for the manufacture of brick and tile in the department of Landes, France, are discussed briefly. M.V.C.

**Common orientation and a classification for crystals based upon a marcasite-like packing.** M. J. BUERGER. *Amer. Mineralogist*, **22** [1] 48–56 (1937). F.J.Z.

**Constitution of zeolite.** L. PASSERINI. *Gazz. Chim. Ital.*, **65** [6] 534–42 (1936).—Six types of zeolite were investigated: analcime ($Na_2O \cdot Al_2O_3 \cdot 4SiO_2 \cdot 2H_2O$), natrolite ($Na_2Al_2Si_3O_{10} \cdot 2H_2O$), heulandite ($H_4CaAl_2(SiO_3)_6 \cdot 3H_2O$), stilbite ($H_4(Na_2,Ca)Al_2Si_6O_{16} \cdot 4H_2O$), chabazite ($(Ca,Na_2)$-$Al_2Si_4O_{12} \cdot 6H_2O$), and scolecite ($CaAl_2Si_3O_{10} \cdot 3H_2O$). The absorption spectra of the crystal water of the first five were found to be the same as for pure water, but for scolecite this was found true only for long wave-length. M.H.

**Crystal lattice and twin crystals of leucite.** J. WYART. *Compt. Rend.*, **203** [19] 938–39 (1936).—The diffraction properties of leucite, $KAlSi_2O_6$, were determined. M.H.

**Dispersion of soil for mechanical analysis by sodium carbonate or sodium oxalate treatment.** A. N. PURI. *Soil Sci.*, **42** [4] 267–72 (1936).—The proposed method consists in the estimation of exchangeable Ca and free acidoid, sodium carbonate or oxalate equivalent to the former and sodium hydroxide equivalent to the latter being subsequently added; the soil suspension is shaken overnight. To attain maximum dispersion, soils rich in organic matter require boiling with $H_2O_2$ or ammonium carbonate in addition to the foregoing treatment. See "Ammonium-carbonate—" *Ceram. Abs.*, **14** [7] 171 (1935). G.R.S.

**Effect of phosphates on the cation-exchange capacity of certain soils.** A. L. PRINCE AND S. J. TOTH. *Soil Sci.*, **42** [4] 281–90 (1936).—The exchangeable calcium, magnesium, potassium, and sodium showed no significant differences in relation to the amount of added phosphates. G.R.S.

**Essential constituent of the "flint clay" of Normandy.** B. BRAJNIKOV. *Compt. Rend.*, **202** [19] 1595–97 (1936).—The varying character of this flint clay was found to be due to its content of phyllite which in this case is a beidellite without silicon, belonging to the series beidellite-nontronite in which $Al_2O_3$ preponderates over $Fe_2O_3$. M.H.

**Formation of structure in soil: I, Structure of soil colloids.** D. I. SIDERI. *Soil Sci.*, **42** [5] 381–93 (1936).—The existence of aggregate phases in soil colloids alters essentially our conceptions regarding their behavior. The electric properties of colloid particles, when they agglomerate into groups, are radically changed as a result of the shrinking of the ion envelope. The properties determined by the nature of the absorbed cations are levelled out in the associated groups. The possibility of spontaneous coagulation, explained by the prevalence of the forces of molecular attraction over those of electrostatic repulsion, is demonstrated. 38 references. **II, Synthesis of aggregates. Bonds uniting clay with sand and clay with humus.** *Ibid.*, [6] 461–81.—The former conception that the particles forming the soil structural aggregate are held together by the tension of the water film is supplemented by the finding that the surface film creates a definite orientation of the particles in relation to one another. The tenacity of the bond between the separate parts of the soil structural aggregate can not be explained by the presence of absorbed Ca. The explanation of the tenacity of this bond lies in the stability of the group arrangement of the particles. The most stable arrangement of particles is the homogeneous one. The formation of nonhomogeneous aggregates in soil-sand-clay and clay-humus may be explained by the same laws which have been found to exist for mineral intergrowths. The impossibility of completely separating soil into its elementary parts is corroborated. In connection with the theory developed, it becomes necessary to revise the theory of soil texture. The subdivision of soil into stable and unstable groupings of particles appears to be more expedient. The influence of external conditions (vegetation, microörganisms, tillage, pressure, freezing, etc.) on the formation of structure can be explained by the swarm theory. 40 references. **III, Mechanism of the swelling of soil.** *Ibid.*, **43** [1] 43–50 (1936).—Water absorption and swelling of soil are determined by the structure of the surface layer of oriented particles. Particular importance is attached, in the case of unstable groupings, to the compactness of the particles at the interface, solid phase-air. Mechanical damaging of the surface layer leads to disintegration. From the viewpoint of the new conceptions concerning soil structure, it becomes necessary to revise the theory of soil morphology. There is no other field in which the internal relation between the shape of the molecule and the crystal would appear with such clearness as in the mesomorphous state. G.R.S.

**Geochemistry of natural glasses.** A. YA. MIKEĬ. *Trudy Vsesoyuz. Mendeleev. S'ezda, 1932*, **2** [1] 451–56 (1935); *Chem. Abs.*, **29**, 7882 (1935).—Results of investigations of the Ukrainian Institute of Physical Chemistry on obsidians and pumices in Caucasia are given. Chemical analyses, determinations of specific gravity, and microscopic study of several samples have been made. The causes of the high $SiO_2$ of obsidian, as compared with pumice, and of hypergenesis were also investigated.

**Gravitational compaction of clays and shales.** HOLLIS D. HERBERG. *Amer. Jour. Sci.*, **31**, 241–87 (1936).—A review of the literature on gravitational compaction shows that speculation has gone far ahead of actual data. New data derived from a study of core samples of undisturbed Tertiary strata in Venezuela are presented. The initial porosity of clay or mud ranges from 70% to more than 90% but under a pressure of 400 to 500 lb./sq. in. the porosity is reduced to 35%. The data obtained from the well samples cover the pressure range 500 to 8000 lb./ sq. in. The rate of decrease in porosity diminishes with increasing pressure. At 8000 lb./sq. in. it is still 8 or 9%. Marked changes in the porosity gradient are observed at 800 lb./sq. in. (30 to 35% porosity) and at 6000 lb./ sq. in. (10%), and these are believed to reflect changes in the process of compaction, which is divided into four stages. (*A*) The initial volume of a fine-grained sediment is dependent chiefly on the volume of the adsorbed film of

water surrounding the particles and on the force of attraction between particles. This last factor is conditioned largely by the presence or absence of electrical charges due to selective adsorption and it controls the original density and looseness of structure to a large extent. The initial stage of compaction is chiefly a gravitational rearrangement of the mode of packing and the expulsion of most of the free water. These changes result from the collapse of the original unstable structure under the increased pressure. (*B*) The second stage is a further dewatering and covers that part of the process between the attainment of a stable mechanical arrangement and the condition in which particles begin to come into actual contact, *i.e.*, until true cohesion sets in. (*C*) The third stage is the complete removal of adsorbed water at the intergranular contacts which takes place at about 30 to 35% porosity. Further reduction in volume occurs only with mechanical deformation such as bending, crushing, or granulation. Recrystallization begins in this stage and the elasticity of the material decreases rapidly. (*D*) The last stage is the slow molecular and chemical readjustment under the high pressures. It starts at a porosity of about 10%. In order to reduce this porosity the pore spaces must be filled by new crystals appearing on the recrystallization. J.B.A.

**Identification of the clay substance in soil by X-ray investigations.** A. JACOB, U. HOFMANN, AND H. LOOFMANN. *Trans. Internat. Congr. Soil Sci., 3rd Congress, Oxford, 1935*, **1**, 85–88; *Chem. Abs.*, **29**, 7550 (1935).—The authors review and outline procedures and results obtained in the examination of 11 samples from Europe and 10 samples of tropical soils. The clay minerals montmorillonite and kaolinite were identified in clay suspensions less than 2$\mu$, and impurities such as quartz as well, but the presence of halloysite was not proved. Some of the tropical soils contained kaolinite without montmorillonite. The latter is relatively resistant to chemical attack and is believed to be the crystalline clay mineral most concerned in base-exchange reactions, as many of the remaining soils contained little or no kaolinite. Quantitative studies indicated that in some cases an important part of the exchange capacity was in a fraction greater than 2$\mu$.

**Index of texture and classification of Philippine soils.** M. M. ALICANTE AND D. Z. ROSELL. *Philippine Jour. Sci.*, **59** [4] 505–11 (1936). R.F.R.

**Interpretation of schistosity.** F. J. TURNER. *Trans. Proc. Roy. Soc. New Zealand*, **66**, 201–24 (1936).—Schistosity, cleavage, foliation, metamorphism, and their various definitions are discussed from the different points of view of American, British, and European geologists. A bibliography of schistosity is included. H.H.S.

**Method of controlling working properties of clays and kaolins by areometric and pycnometric specific gravities.** M. F. YUKNAT. *Keram. & Steklo*, **12** [11] 18–23 (1936).—Details of procedure and directions for testing the liquefying properties of clay and kaolin are given, and results are tabulated. M.V.C.

**Method for determining porosity of the soil.** G. TORSTENSSON AND SIGURD ERIKSSON. *Soil Sci.*, **42** [6] 405–17 (1936).—A description is given of a new method for the direct measurement of air space in soils based on Boyle's law. The apparatus (the porosimeter) also permits calculation, in a simple way, of the specific gravity, water content, and soil substance. G.R.S.

**Milling and classification of feldspars.** V. V. KELSEY. *Glass Ind.*, **17** [10] 333–35 (1936).—There are six classifications of feldspar which are modified as to particle size and by a great variety of chemical compositions. The need for further simplification of specifications is made clear. E.J.V.

**Notes on Missouri halloysite.** FRANK J. ZVANUT. *Jour. Amer. Ceram. Soc.*, **20** [3] 84–87 (1937).

**Podsols and brown forest soils: I.** KARL LUNDBLAD. *Soil Sci.*, **37** [2] 137–55 (1934).—The acid-oxalate method of Tamm (*Ceram. Abs.*, **14** [7] 172 (1935)) is presented and discussed together with experiments made to illustrate its applicability. The method gives a measure of the weathering and is useful in characterizing different soil types. 32 references. For Part II see *ibid.*, **16** [1] 40 (1937). G.R.S.

**Properties of clay fractions.** C. E. MARSHALL. *Trans. Internat. Congr. Soil Sci., 3rd Congress, Oxford, 1935*, **1**, 88–90; *Chem. Abs.*, **29**, 7550 (1935).—A brief review and critical discussion are given. It is pointed out that increase in exchange capacity does not keep pace with increase in surface as particle size decreases, an indication that exchangeable cations are largely held inside the clay lattice, and there is evidence that such cations occupy definite positions. The clays should therefore be considered alumino-silicates rather than colloidal mixtures of hydrated oxides. It is not possible to predict a close relation between chemical composition and colloidal properties, for the latter are largely dependent upon surface layers in contact with $H_2O$. The crystal lattice theory is well suited to base-exchange studies, in spite of failures so far to formulate a satisfactory base-exchange equation.

**Properties of the hydroxyl groups of clay as a basis for characterizing a mineral soil.** WALTER THOMAS. *Soil Sci.*, **42** [4] 243–59 (1936).—By treating a soil with increasing amounts of solutions of HCl and of $Ba(OH)_2$ in low concentrations, differences in specific properties of the three types of hydroxyl groups of clays may be used as a means for the rapid characterization of a soil with respect to the degree of unsaturation, total replaceable bases, "free" aluminum and iron hydroxides, phosphoric acid required to satisfy the Al and Fe, lime requirement, availability of the different states of the replaceable potassium, and changes produced by cultivation and fertilizer treatment. 32 references. G.R.S.

**Research on national raw materials for ceramics in Italy. Clay for the manufacture of stoneware.** F. POZZI. *Corriere Ceram.*, **17** [11] 315–21 (1936).—P. shows that any clay which does not contain carbonates can be used for the manufacture of stoneware if, with the necessary corrections in the quartz and feldspar contents, it is made to conform to the limits of the molecular formula given: 10.00 to 20.00 $SiO_2$·2.00 to 4.5 $Al_2O_3$ : 1RO (RO = CaO + MgO + FeO + $K_2O$ + $Na_2O$). The chief condition is that the clay should not react in a test with a few drops of HCl. M.V.C.

**Soil swelling: I, Swelling of soil in water considered in connection with the problem of soil structure.** D. I. SIDERI. *Soil Sci.*, **41** [2] 135–51 (1936).—The study of the phenomena of the swelling of soil that keeps its natural

structural condition allows investigation of the problem of soil structure from a new point of view. A method is elaborated, and a form is evolved for a quantitative expression of the porosity changes caused by absorption of water by soil. Definitions of the "index of texture stability" ($S$) and of "swelling water" ($Wq$), founded on the sharp difference between capillary imbibition and swelling proper, are introduced. Swelling water may be considered as the form of expressing the hydrophillic property of soil. Soil swelling is considered as a process of changes arising in the properties of soil at the interface, soil colloids/water. This process leads to a change in the structure of soil and to an increase in its degree of dispersion. A quantitative expression of this process is possible in the form of "swelling water," which represents a more characteristic indication of swelling than the increase of volume. A method is proposed for a differential analysis of soil porosity, providing for its subdivision into noncapillary, capillary, and submicroscopic porosity. For Part II see *Ceram. Abs.*, **16** [1] 41 (1937). G.R.S.

**Spectrographic examinations of colorless and blue halite.** T. G. KENNARD, DAVID H. HOWELL, AND M. P. YAECKEL. *Amer. Mineralogist*, **22** [1] 65–67 (1937).—No difference in chemical composition was observed between the colorless and blue varieties which have been obtained from the same specimen; the blue color, however, is structural rather than pigmental. F.J.Z.

**Thiocyanate test for soil reaction. A modified technique and a method of recording results.** L. W. RAYMOND. *Jour. Soc. Chem. Ind.*, **55** [20] 138–39T (1936).—R. describes a technique for the thiocyanate test for soil acidity, to which greater precision is given by the use of a comparator whereby numerical values can be assigned to the red colors developed. G.R.S.

BOOK AND BULLETIN

**Economic Geology of Mineral Deposits.** ERNEST R. LILLEY. Henry Holt & Co., New York, 1936. x + 811 pp., 301 figs. Price $5.00. Reviewed in *Econ. Geol.*, **31** [12] 882–84 (1936). J.L.G.

**Outline of the mineral resources of Virginia.** WILLIAM M. MCGILL. *Virginia Geol. Survey Bull.* 47 [Education Series, No. 3] xii + 81 pp. (1936).—A summary report on the mineral resources of Va., based upon previous publications and recent field work, is presented. The report contains a concise discussion of the most important mineral resources in the State, including coal, construction materials, gold, limestone, dolomite and calcareous marl, manganese, other metallic deposits, and nonmetallic resources. The main features of each kind of mineral deposit are briefly described. The distribution of the chief mineral resources is given on a series of seven maps which show coal-bearing areas, distribution of construction materials, gold districts, and distribution of calcareous deposits, manganese deposits, metallic deposits, and nonmetallic resources. The discussion of nonmetallic resources includes data on barite, clay, diatomite, emery, feldspar, gypsum, kaolin, kyanite, mica, ocher, salt, silica, soapstone, and talc. A.C.BEVAN

## Chemistry and Physics

**Active oxides: No. 99, Solubility of a mixture of magnesium oxide and iron oxide in the course of aging.** G. F. HÜTTIG AND E. FEIDLER. *Kolloid-Z.*, **75** [2] 170–84 (1936).—Portions of an equimolecular mixture of strongly ignited MgO and $Fe_2O_3$ were heated to various high temperatures, and the solubilities in HCl, magnetic susceptibilities, and, in a few special cases, the X-ray patterns were determined and compared with check determinations on the pure compounds. Solubilities of pure MgO and of pure $Fe_2O_3$ decrease with increasing preheating temperature. The solubilities of both components of the mixture are reduced when aging without activation occurs. Activation of the mixture during heating causes the solubility of the activated component ("actuarius") to increase while that of the activator ("actor") decreases. This oxide mixture is compared with mixed catalysts in general, with reference to the relation between the solubility of a system and its free energy. For No. 92 see *Ceram. Abs.*, **15** [4] 133 (1936). F.P.P.

**Adsorption of aluminum hydroxide by kieselguhr.** E. C. C. BALY AND W. P. PEPPER. *Nature*, **136** [3427] 28 (1935).—Aluminum hydroxide is readily adsorbed by kieselguhr (diatomaceous earth) to form a remarkably stable adsorption complex. The hydroxide is deposited by the slow addition of a small excess of ammonia to a de-aired suspension of 10 g. of specially purified Superfloss kieselguhr in 100 cc. of 2% ammonium nitrate solution containing a known amount of aluminum nitrate. From the amount of aluminum hydroxide adsorbed and from the resulting electrokinetic potential (zeta) of the particles, as shown by their movement in an electric field in $N/10$ acetic acid, it is concluded that aluminum hydroxide is adsorbed first as a unimolecular layer with a zeta value of 75.4 mv. This layer then may adsorb a second unimolecular layer with a drop of zeta to 61.2 mv. This layer has the same properties as the unadsorbed substance. The changed electrokinetic potential for surfaces containing the same number of molecules indicates that the molecules in the first adsorbed unimolecular layer must be activated in some manner. Further addition of aluminum hydroxide to the second layer does not change the zeta value of 61.2 mv., which is that of free unsupported aluminum hydroxide in $N/20$ acetic acid. See *Ceram. Abs.*, **15** [9] 286 (1936). J.L.G.

**Analytical chemistry of tantalum, niobium, and their mineral associates. Observations on phosphorus, vanadium, and a tannin precipitation series.** W. R. SCHOELLER AND H. W. WEBB. *Analyst*, **61** [726] 585–90 (1936).—Phosphoric acid is occluded in the earth-acid precipitate produced by tartaric hydrolysis; it may be determined in the precipitate by fusion with NaOH, which produces soluble Na phosphate but insoluble tantalate and niobate. Vanadium may be separated from Ta and Nb(Cb), as it is not occluded in the tartaric precipitate but is quantitatively precipitated by tannin. A tannin precipitation series is Ta, Ti, Nb, V, $Fe'''$, Zr, Hf, Th, U, and Al, the first being precipitated at the greatest acidity. See *Ceram. Abs.*, **15** [10] 313 (1936). H.H.S.

**Application of the theory of thermal oscillation to the field of meso-phases ("liquid crystals").** H. ZOCHER. *Kolloid-Z.*, **75** [2] 161–63 (1936).—Failure of the Ornstein and the Bose applications of the swarm theory to explain phenomena on thin and on thick nematic layers is discussed. It is shown that the theory of thermal oscillations satisfactorily explains Maugin sparking phenomena, clouding of similarly oriented fields, and temperature variations of the various classes of anisotropy. F.P.P.

**Application of viscometry and plastometry to problems of applied mineralogy.** M. P. VOLAROVICH. *Trudy Vsesoyuz. Nauch.-Issledovatel. Inst. Mineral. Syr'ya*, No. 66, 56 pp. (1934); *Chem. Abs.*, **29**, 4992 (1935).—V. reviews the general concept of viscosity and plasticity, the methods used for measuring plasticity of mineral suspensions, and the application of such methods at high temperatures. References are appended. The apparatus of Volarovich for measuring plasticity of clay and similar suspensions (Volarovich and Tolstoi, *Ceram. Abs.*, **13** [10] 275 (1934)) is described, and the results of such measurements are compared with those obtained by the apparatus of Tolstoi (*Zhur. Fiz. Khim.*, **5**, 28 (1934)). For measuring viscosities at high temperatures the proposed apparatus consists also of two coaxial cylinders made from a Pt-Ir alloy, but the rotating cylinder is the outer one. The apparatus is immersed in an electric oven of special design. Results obtained with $SiO_2$-$Al_2O_3$-CaO slags are in general agreement with the results of other investigators. Viscosity of slags containing 28 to 36% $TiO_2$ is tabulated. The addition of NaCl to such slags has little effect in lowering their viscosity. The effect of $Na_2O$ is also small and sometimes in the opposite direction. It is of interest that the decrease in acidity of such slags, as determined by the $(TiO_2 + SiO_2)/(CaO + MgO)$ ratio, is accompanied by increase in viscosity at the melting point. In general, the work with $TiO_2$ slags is complicated by their instability. Work with glasses and coal tars indicated that they behave like Newtonian liquids and do not exhibit plastic properties in the liquid state. Certain melts, particularly those containing $TiO_2$, are plastics. This is explained by the colloidal nature of such clays. Work with enamels used for manufacturing kitchenware shows that the addition of $Na_2B_4O_7$ increases their viscosity-temperature gradient considerably. Results on measuring viscosities of minerals used in glass manufacture (basalt, teschenite, andesite, obsidian, diabase, etc.) are also given. Their viscosity-temperature gradient is considerably greater than that of glass. Comparison of the viscosity of minerals with their composition indicates that basic substances decrease their viscosity in the molten state while acidic substances have a reverse effect. The plastic properties appear when certain components of such systems begin to crystallize, which is particularly noticeable with minerals of low viscosity at high temperatures. Such measurements are helpful for determining the suitability of various minerals for manufacturing glass. They also explain certain geological phenomena in the neighborhood of volcanoes.

**Bibliography of ceramic microscopy.** T. N. MCVAY. *Bull. Amer. Ceram. Soc.*, **16** [2] 33–61 (1937).

**Chemical and X-ray investigations on the mineral sorption substance in soils.** A. JACOB, U. HOFMANN, H. LOOFMANN, AND E. MAEGDEFRAU. *Beiheft Z. Ver. Deut. Chem.*, No. 21; *Angew. Chem.*, **48**, 585–86 (1935); *Chem. Abs.*, **29**, 8197 (1935).—The following properties of soils were determined: ratio of sesquioxides to $SiO_2$, ratio of $Al_2O_3$ to $SiO_2$, $S$ and $T$ values, behavior on treating with concentrated HCl, and X-ray patterns. The results indicated that mixed gels are not the media of exchange adsorption in soils. It is to be concluded that the base exchange in soils is effected by the crystalline minerals kaolinite and montmorillonite and a clay mineral, $x$, which needs further investigation. The clay minerals probably were not formed from amorphous substances, but represent a very stable decomposition product of soil-forming minerals.

**Clay and the colloidal state.** MARCEL ANSAY. *Agricultura*, **38**, 197–205 (1935); *Chem. Abs.*, **29**, 7751 (1935).—A. discusses colloidal solutions, particularly of clay colloids, their electrolytic properties, stability of the micellae, effect of electrolytes, and preparation of the solutions. An electrophoresis apparatus is described.

**Crystalline boron.** D. P. MELLOR, S. B. COHEN, AND E. B. UNDERWOOD. *Jour. Australian Chem. Inst.*, **3**, 329–33 (1936).—Dark silver-gray crystals of B were obtained by reducing $BBr_3$ with dry hydrogen. Their density was 2.36 and their hardness the same as that of silicon carbide. H.H.S.

**Current-conducting properties of slags in electric furnaces: I.** A. WEJNARTH. *Trans. Electrochem. Soc.*, **65**, 319–29 (1934); *Brit. Chem. Abs.-B*, **53** [29] 633 (1934).—Silicates of the series $2ROSiO_2$, $4RO3SiO_2$, and $ROSiO_2$, where R is Fe + Ca in various proportions, were prepared by fusion of the pure oxides under $N_2$ in an electrically heated crucible of pure Fe. Their electrical conductivity, $k$, was measured at 1344 to 900°, using alternating current, with the crucible as one electrode and an adjustable vertical electrode just dipping into the silicate melt. With fall in temperature, $k$ decreases regularly to the freezing point, where there is a sharp drop. Silicates rich in Fe have higher conductivities, and retain an appreciable volume of $k$ even in the solid state; an increasing proportion of Ca lowers $k$ progressively. The variation of $k$ with temperature for the various compositions and the freezing point are shown graphically; composition curves are recorded for the three series of silicates.

**Determination of iron in sands by the spectrographic method.** PIERRE GILARD, LÉON DUBRUL, AND FRANÇOIS JAMAR. *Verre & Silicates Ind.*, **7** [35] 414–17 (1936).—An arc was formed between two electrodes of electrolytic copper (separated by 3 mm.; intensity 4 amp., fed by continuous circuit 120 v. with resistance, 0.01 mm.; duration of exposure 30 or 60 sec. with logarithmic discontinuous circuit). The sand is placed on the cathode. The method gives sufficient precision above 0.05% $Fe_2O_3$; under this concentration it should give good results but requires a complementary test with electrodes which are spectrographically pure. In analyses in series, 10 min. per sand may be counted on. Tables of the determination are given. M.V.C.

**Determination of lead in potable waters.** S. L. TOMPSETT. *Analyst*, **61** [726] 591–97 (1936).—The presence of Pb in normal human dietaries has been established. Pb in water may be estimated colorimetrically by diphenylthiocarbazone. If Fe content is high, a preliminary sepa-

ration of Pb is necessary, a suitable reagent being Na diethyldithiocarbamate. H.H.S.

**Determination of small amounts of platinum in minerals, alloys, scrap material, etc. Separation and concentration of platinum by coprecipitation with tellurium.** S. KUHNEL HAGEN. *Mikrochemie*, **20**, 180–88 (1936).—Tellurium may be reduced from an acid solution (HCl) of sodium tellurate with sulfuric acid under such conditions that only the platinum metals (gold, selenium, molybdenum, and mercury) will be precipitated. Other metals are either not precipitated at all or only in very slight amounts. This fact makes it possible to separate and determine very small admixtures of platinum (less than 0.0001%). A series of tests is described. L.E.T.

**Exact determination of silica in sands and aluminous silicates.** ANDRÉ SUTTOR. *Ing. Chim.*, **19**, 32–42, 57–63 (1935); *Chem. Abs.*, **29**, 7867 (1935).—S. reviews opinions as to the need of 1, 2, or 3 evaporations to render the silica completely insoluble and as to the different temperatures of heating the residue. A mixture of Na and K carbonates in equimolecular proportions was used as a flux to reduce fusing temperature to 490°. S. discusses the various acids of silica that may be formed during analysis. The method of analysis used was that given in "Cours d'analysis quantitative des Produits des Industries chimiques" by Meurice, with slight changes. A porcelain evaporating dish is used instead of a glass flask when dissolving the fused sample and only a little water is used. Results of tests are tabulated to show the effect of duration of the drying period at temperatures varying from 100 to 150°. The analyses show that a single evaporation does not render the silica completely insoluble. In one series of tests the residue was treated with concentrated HCl and then heated several minutes on a boiling water bath. The quantity of silica appearing in the second evaporation was greater than when the cold acid was used. The tables showing the effect of the presence of Al and Fe salts indicate a slight entrainment of Al. Tables indicating a similar effect when Ca and Mg are present are given. Two silico-aluminous earths containing 40 and 20% alumina, respectively, were tested and the results are given. In all cases two evaporations were found necessary. S. recommends a drying period of $2^1/_2$ hr. at a temperature of 130°.

**Extraction of aluminium oxide from clay with ammonium sulfate. Carbon-containing shale of Khakassia as a raw material for alumina.** A. P. PENTEGOV, Y. P. NIKOLSKAYA, AND V. A. ANZELEVICH. *Legkie Metally*, No. 7–8, pp. 27–31 (1932); No. 1, pp. 14–16 (1933); *Chem. Zentr.*, **1933, i**, 3611; **ii**, 1412; *Brit. Chem. Abs.-B*, **54** [1] 20 (1935).—Kaolin ($Al_2O_3$ 33.13, $Fe_2O_3$ 0.6%) was sintered for 28 min. with $(NH_4)_2SO_4$ at 400° and extracted for 2 hr. with $H_2O$ [90% yield of Al as $(NH_4)_2SO_4$, $Al_2(SO_4)_3$, $24H_2O$]. The ash from the shale oil (32 to 40% $Al_2O_3$) was extracted with $(NH_4)_2SO_4$, as above, 70 to 80% of the $Al_2O_3$ being rendered soluble.

**General rôle of composition in polymorphism.** M. J. BUERGER. *Proc. Nat. Acad. Sci.*, **22** [12] 685–89 (1936).—Change of composition in a given crystal phase is brought about by solid solution. The simple types of solid solution are (1) addition or interstitial solid solution, (2) proxy solution, and (3) omission solution. B. considers the alterations imposed by these conditions on the cluster vibration theory of polymorphism. In general, if an impurity is to be housed, the modification best adapted to housing it will form. B. recommends that Barth's definition of polymorphism be amended by dropping the constant chemical composition stipulation to read "Polymorphism includes every possible difference encountered in the crystalline structure of a substance, excepting homogeneous deformations." J.L.G.

**Hydroxyquinoline process for rapid determination of alumina.** W. STEGER. *Ber. Deut. Keram. Ges.*, **16** [12] 624–27 (1935).—A comparison was made of the determinations of alumina by the use of hydroxyquinoline, ammonia, and ammonium phosphate. When hydroxyquinoline is used, the accuracy is as great and there is a saving in chemicals used, gas burned, and time required for the analysis. E.J.V.

**Interrelations of compressibility, melting point, solubility, valence, and other properties of the halides of alkali and alkaline earths.** SOFRONIO BALCE. *Philippine Jour. Sci.*, **60** [3] 251–54 (1936). R.F.R.

**Investigation into the oxidizing power of basic slag: I, Determination of the binary diagram $CaO$–$Fe_2O_3$. II, Determination of the dissociation pressures of $Fe_2O_3$, $CaO{\cdot}Fe_2O_3$, and $2CaO{\cdot}Fe_2O_3$.** J. WHITE, R. GRAHAM, AND R. HAY. *Jour. Iron & Steel Inst.* [London], **131**, 91–113 (1935).—The pseudobinary system $Fe_2O_3$–CaO (pseudobinary because of the dissociation of $Fe_2O_3$ at high temperatures) contains two compounds, $CaO{\cdot}Fe_2O_3$ and $2CaO{\cdot}Fe_2O_3$. The properties of the phases present are as follows: *$Fe_2O_3$*, refractive index greater than 2.95, less than 3.10; deep red; slightly pleochroic; straight extinction; uniaxial; negative; apparent melting point 1595°C but this figure is believed to be low owing to dissociation. *$CaO{\cdot}Fe_2O_3$*, refractive index between 2.5 and 2.6; reddish brown, brown in thin sections; pleochroic; high polarization colors; straight extinction; uniaxial; melt made up of dark needles having a metallic luster, which, though very hard, could be scratched with a knife. The compound melts incongruently at approximately 1220°C and is completely liquid at 1240°C. *$2CaO{\cdot}Fe_2O_3$*, refractive index between 2.3 and 2.36; light brown; decidedly pleochroic; nearly straight extinction; biaxial; melt tabular in appearance and not so hard as the monocalcium ferrite; melts incongruently at approximately 1440°C and is completely liquid at 1450°C. There is a eutectic at 90 wt. % $Fe_2O_3$ and approximately 1205°C. The dissociation pressure of $Fe_2O_3$ is appreciable at 1100°C, increases rapidly with temperature, and is of the order of $5 \times 10^3$ atmospheres at its melting point. $Fe_2O_3$ is partially soluble in $Fe_3O_4$, the solubility ranging from about 10 wt. % at 1100°C to 30% at 1400°C. $Fe_3O_4$ is also soluble in $Fe_2O_3$, the solubility increasing from 10 wt. % at 1100°C to about 20% at 1400°. A partial diagram for the system $Fe_2O_3$–$Fe_3O_4$ is given. The dissociation of $CaO{\cdot}Fe_2O_3$ and $2CaO{\cdot}Fe_2O_3$ was investigated. Below the peritectic temperatures the oxygen pressure is infinitesimal; at high temperatures the pressure is due to dissociation of $Fe_2O_3$ resulting from the peritectic reactions. The oxygen pressure of the ferrites falls rapidly as FeO increases. CaO has a marked stabilizing effect on $Fe_2O_3$. J.B.A.

**Kinetic basis of crystal polymorphism.** M. J. BUERGER.

*Proc. Nat. Acad. Sci.*, **22** [12] 682–85 (1936).—B. offers a theory of polymorphism which explains the existence of a substance in several different crystal modifications and the inversions of these, with change of temperature, from one form to another in terms of vibration modes of the unit clusters which compose the crystal. These vibration modes assumed by the clusters may change with change in temperature. The clusters may be molecules, a molecular group of atoms, or a coördination group of atoms. Each of the atoms has three degrees of freedom which may be combined in various ways to give characteristic cluster vibrations. Six degrees of freedom may be ascribed to translations and rotations of the clusters as bodily units. These are "outer" vibration modes. The remaining $3n - 6$ degrees of freedom correspond to internal cluster distortion or "inner" vibration modes. The tetrahedral $SiO_4$ group is a symmetrical cluster whose $3 \times 5 - 6$ or 9 inner vibration modes produce only 4 geometrically distinct modes. The other five are identical with these except for orientation. The excitation of outer or inner modes will depend on the relative strengths of intercluster *vs.* intracluster bindings. Excitation of outer modes occurs readily with molecular and molecular group crystals, while excitation of inner modes may be expected with linked coördination structures. "For a given temperature, there is a preferred cluster vibration mode (or mode combination) leading to least vapor pressure; this vibration mode requires the cluster to have a certain dynamic symmetry. Stable crystals form at this given temperature by the building up of a crystal structure such that this preferred symmetry is provided by the structure for the cluster." Examinations of some known one-component systems are promised in forthcoming papers. J.L.G.

**Melting of danburite. A study of liquid immiscibility in the system $CaO$–$B_2O_3$–$SiO_2$.** G. W. Morey and Earl Ingerson. *Amer. Mineralogist*, **22** [1] 37–48 (1937).—This study confirms the existence of a band of immiscibility across the ternary system $CaO$–$B_2O_3$–$SiO_2$, due to the fact that on melting danburite, $CaO$–$B_2O_3$–$SiO_2$, two liquid layers are formed. F.J.Z.

**Melting-point diagram of the system $ZrO_2$–$SiO_2$.** N. Zhirnova. *Zhur. Obshchel Khim.*, **4**, 1464–70 (1934); *Chem. Abs.*, **29** [12] 3902 (1935).—The melting points of mixtures of $ZrO_2$ and $SiO_2$ were determined with an accuracy of ±20° as follows:

| $ZrO_2$ (mol. %) | Melting point | $ZrO_2$ (mol. %) | Melting point |
|---|---|---|---|
| 100.00 | 2715° | 32.00 | 2060° |
| 95.32 | 2680 | 30.08 | 2020 |
| 95.00 | 2670 | 28.00 | 2000 |
| 84.11 | 2570 | 25.00 | 1935 |
| 78.07 | 2510 | 23.85 | 1925 |
| 76.80 | 2485 | 19.74 | 1885 |
| 70.00 | 2405 | 8.87 | 1805 |
| 67.54 | 2360 | 6.96 | 1795 |
| 61.14 | 2275 | 6.09 | 1785 |
| 54.55 | 2330 | 4.00 | 1745 |
| 47.85 | 2420 | 3.00 | 1705 |
| 40.31 | 2340 | 0.72 | 1710 |
| | | 0.00 | 1715 |

The existence of a compound, $ZrO_2 \cdot SiO_2$, melting at 2430° and not at 2550° as reported in the literature, was established. The system $ZrO_2$–$SiO_2$ has two eutectics, at 2220° and 1705°, corresponding to 42 and 97 mol. % $SiO_2$, respectively. The melting diagram shows a field of solid solutions of $SiO_2$ in $ZrO_2$ up to about 10 mol. % $SiO_2$.

**Method for the complete analysis of chrome-iron ores.** Yu. Yu. Lur'e. *Zavodskaya Lab.*, No. 3, pp. 21–25 (1932); *Chem. Zentr.*, **1934, ii**, 3149; *Chem. Abs.*, **29**, 6530 (1935).—The decomposition method is based upon that of Cunningham and McNeill. A 0.5-g. sample in a porcelain or Pt crucible is treated with 25 cc. $H_2SO_4$ (1:1) and 5 cc. $HClO_4$ (density 1.54) and heated on the sand bath until persistent fumes of $SO_3$ are evolved. After cooling, it is diluted with water and filtered; the precipitate is washed with dilute $H_2SO_4$ and hot water, and ignited in a Pt crucible. The $SiO_2$ contaminated with metallic oxides is weighed. The $SiO_2$ content is the loss in weight upon treatment of the residue with $H_2SO_4$ and HF. After the removal of $SiO_2$ the residue is fused with $K_2S_2O_7$, dissolved in $H_2SO_4$, and added to the first filtrate, and Cr, Mn, Fe, Al, Ca, and Mg are determined upon the combined solutions.

**Method of interpretation of petrofabric diagrams.** Horace Winchell. *Amer. Mineralogist*, **22** [1] 15–36 (1937).—Two statistical methods which are easily and conveniently applied to petrofabric diagrams are described. F.J.Z.

**Methods of measuring explosive pressures. Comparison of crushing with the piezoelectric quartz method: I, Device for studying explosive pressures using the piezoelectric properties of a quartz sheet.** A. Langevin. *Jour. Phys. & Radium*, **7** [11] 448–50 (1936).—Theoretical background, description of apparatus, and methods of amplifying the impulses are presented. **II, Comparison of pressure-temperature curves deduced (*a*) from the measured crushing and (*b*) from the piezoelectric quartz measurements.** Henri Muraour, A. Langevin, and G. Aunis. *Ibid.*, pp. 450–52.—Within the limits of the experimental conditions chosen, very satisfactory agreement between results by the two methods is reported. F.P.P.

**Outline for examination of crystal grains.** K. E. Buck. *Bull. Amer. Ceram. Soc.*, **16** [2] 61–62 (1937).

**Phosphorescent glass. Influence of crystallization.** Maurice Curie. *Compt. Rend.*, **203** [20] 996–97 (1936).—Glass of zinc borate, $2B_2O_3 \cdot 3ZnO$, was prepared in the vitreous and crystalline modifications. The vitreous piece did not show a distinct phosphorescence, but the crystalline modification showed a very strong yellow, durable luminescence after irradiation with ultra-violet light. The crystalline residue from attack by HCl of the vitreous modification showed the same strong luminosity. M.H.

**Preparation of barium aluminate for production of alumina (Kuznetzov-Shukovski process).** F. Chistyakov. *Legkie Metally*, No. 3, pp. 30–31 (1932); *Chem. Zentr.*, **1933, i**, 3610; *Brit. Chem. Abs.-B*, **54** [1] 20 (1935).—The raw material, consisting of bauxite, witherite, Fe filings, and combustible material (14%, to facilitate agglomeration), is agglomerated. The product is reduced in the electric furnace with the addition of more fuel ($BaCO_3 \rightarrow BaO$, $Fe_2O_3 \rightarrow Fe$, $SiO_2 \rightarrow Si$).

**Proposals for the chemical investigation of ceramic raw materials and products.** M. Pulfrich. *Ber. Deut. Keram. Ges.*, **17** [8] 381–87 (1936).—Notes are given on the

chemical analysis of materials containing clay substance, with reference chiefly to the determination of $SiO_2$, $Al_2O_3$, $TiO_2$, $Fe_2O_3$, CaO, MgO, $K_2O$, $Na_2O$, and in some cases $Mn_3O_4$, loss on ignition ($H_2O + CO_2$ + organic material), and $SO_3$. E.J.V.

**Quantitative separation of aluminium and beryllium (glucinum).** J. DEWAR AND P. A. GARDINER. *Analyst*, **61** [725] 536–38 (1936).—Gmelin's old method of decomposing Na beryllate by boiling with a large volume of water can be made accurate if the amount of Al present is not greatly in excess of the Be; otherwise, addition must be made of a known amount of Be to adjust the ratio. H.H.S.

**Rapid analysis of clays.** S. S. ZHUKOVSKAYA AND S. T. BALYUK. *Zavodskaya Lab.*, **3**, 485–88 (1934).—Previous work (*Ceram. Abs.*, **15** [10] 315 (1936)) is continued. The analysis is fulfilled with the aid of *o*-oxyquinoline (oxine) and Cupferon (ammonia salt of nitrosophenyl hydroxylamine ($C_6H_5 > N{-}O{-}NH_4$)). The use of alkalis is eliminated. Ti is separated from Al in the presence of oxalic acid. The relation between acidity, the excess of oxine, and the concentration of Fe, Al, and Ti salts has been established. Fe was precipitated in a 5% acetic solution with the aid of 10 cc. of oxine in the presence of 4 g. of tartaric acid; 3 g. of oxalic acid and 0.3 cc. (for 100 cc.) of acetic acid were added to the filtrate obtained, and Ti was precipitated from it with the aid of 10 cc. of 1.5% oxine. Oxyquinoline Ti was separated by filtration the next day; an inconsiderable increase of the concentration of acetic acid delays its isolation for 8 to 10 hr.; if the concentration of acetic acid is under 0.1%, aluminum oxyquinolate precipitates together with Ti. With Cupferon, Ti reacts as follows: $TiCl_4 + 4CuHgN_3O_2 = Ti(C_6H_5N_2O_2)_4 + 4NH_4Cl$. The precipitation of Ti in the presence of Al is rapid and exact in a solution of hydrochloric acid; Al does not precipitate under these conditions. The determination of Ti by Cupferon was undertaken in the presence of tartaric acid and without it, and in these conditions in the presence of Al. The latter was precipitated by oxine in an ammonia medium (2% vol. solution in presence of tartaric acid). Ti was also precipitated in the same way. When precipitating Fe with oxine no heating was undertaken. The concentration of acetic acid did not surpass 5%; in the case of a concentration of under 3% a partial precipitation of Ti oxyquinolate took place. The metals are precipitated by oxine according to the reaction: $3C_9H_7ON + AlCl_3 = Al(C_9H_6ON)_3 + 3HCl$. The further determination can be fulfilled by weight (as a quinolate or the respective oxide) or by volume. The latter is based on the property of oxine to form, with Br, dibromo-*o*-oxyquinoline, $C_9H_5Br_2ON$. After the solution of oxyquinolate in HCl, the free oxine that has been isolated is bromated, the excess of bromine is determined iodometrically, and the quantity of metal is computed from the bromine found. $SiO_2$ is determined separately. The method was used with a mixture of Al, Fe, Ti, Ca, Mg salts with clay and grog and gave satisfactory results; the deviations of the data from those obtained by the classical method take place on account of the inexactitude of the latter. The time needed for the analysis is 2 to 3 days instead of 4 to 5 days. The method is recommended for laboratory practice. P.B. & E.S.

**Rapid determination of alumina by the hydroxyquinoline process.** FRITZ KLASSE. *Ber. Deut. Keram. Ges.*, **16** [12] 628–31 (1935).—The method for determining alumina by use of hydroxyquinoline and a simplified determination of titanium oxide are given in detail. See *Ceram. Abs.*, **14** [6] 151 (1935). E.J.V.

**Rapid method of determining aluminium in clays and grog.** S. S. ZHUKOVSKAYA AND M. I. VOLUINETZ. *Zavodskaya Lab.*, **3** [7] 616–19 (1934). P.B. & E.S.

**Redetermination of the atomic weight of aluminum.** JAMES I. HOFFMAN AND G. E. F. LUNDELL. *Jour. Research Nat. Bur. Standards*, **18** [1] 1–18 (1937); R.P. 957. Price 5¢. Weighed portions of the metal were converted to the hydroxide and sulfate, respectively. These were then heated until they were changed to the oxide, $Al_2O_3$, which was ignited at 1200 to 1300°C. The value for the atomic weight based on this work is 26.974 ± 0.002. R.A.H.

**Selenium dioxide—a new oxidizing agent.** H. L. RILEY. *Sci. Jour. Roy. Coll. Sci.*, **5**, 7–15 (1935); *Chem. Abs.*, **29**, 5370 (1935).—The production, the oxidizing action on organic compounds, and the spectrum of $SeO_2$ are reviewed. The causes of the highly specific nature of the oxidizing action are obscure. It appears that $SeO_2$ provides O atoms in a very low energy state. 26 references.

**Solubility of quartz in hydrofluosilicic acid.** CHARLES B. MOKE. *Jour. Ind. Hyg. & Toxicol.*, **18** [5] 299–300 (1936).—Since pure quartz was found as a residue after treatment of foundry dusts with hydrofluosilicic acid for two days, doubts were expressed as to the insolubility of extremely fine quartz. Tests were made on quartz ground in a ball mill and elutriated into various grain-size fractions; 0.5-g. samples were subjected to the action of hydrofluosilicic acid at room temperature for 48 hr. Results obtained indicate that quartz is soluble to a fairly great extent. If sufficient time and acid are employed, all of the quartz would undoubtedly go into solution. The rate of solubility of quartz increases greatly with decrease in grain size. E.J.V.

**Stabilities of aluminates.** H. ZUR STRASSEN. *Z. Electrochem.*, **41**, 476–78 (1935); *Chem. Abs.*, **29**, 7162 (1935); for abstract see *Ceram. Abs.*, **14** [7] 167 (1935).

**Study of the solid solutions of ferrous sulfide with sulfur, selenium, and arsenic.** A. MICHEL. *Compt. Rend.*, **203** [20] 1004–1006 (1936).—Experiments which established the solid solutions 6FeS + S, 6FeS + Se, and 12 FeS + As are described. Some physical constants were determined. M.H.

**Titanium dioxide; precipitation factors affecting pigment properties.** C. LIGORIO AND L. T. WORK. *Ind. Eng. Chem.*, **29** [2] 213–17 (1937).—Basic sulfate solutions in which the ratio of titanium dioxide to sulfuric anhydride is varied have been prepared from commercial titanium sulfate by (1) direct calcination, (2) extraction with acetone, and (3) reaction in aqueous solutions with orthotitanic acid. The ratios obtained were, respectively, 1/1, 1/1.59, 1/0.65. Titanium dioxide pigment of good hiding power has been produced from solutions of basic titanium sulfate by diluting the solution to create seed nuclei, a process called "autoseeding." The turbidities or hiding powers of pigments prepared from different compositions of the system titanium dioxide–sulfuric anhydride–water

have been plotted in a ternary diagram. These results show that the pigments of the best hiding powers were prepared from solutions with a titanium dioxide concentration falling between 13 and 19% and ratios ranging from 1/1 to 1/0.65. Seeding opalescence occurs at different hydrogen-ion concentrations with different concentrations of solutions. Illustrated. F.G.H.

**Viscosity and plasticity of disperse systems: VI, Effect of temperature and electrolytes on the plastic properties of kaolin.** M. P. WOLAROWITSCH AND D. M. TOLSTOI. *Kolloid-Z.*, **73** [1] 92–96 (1935); see *Ceram. Abs.*, **16** [3] 101 (1937). **VII, Plastic flow in an apparatus with cylinders displaceable lengthwise.** D. M. TOLSTOI. *Kolloid-Z.*, **73** [1] 96–101 (1935).—A method for determining the flow resistance and shearing modulus of high concentration mineral suspensions is described. The apparatus was designed particularly to eliminate surface gliding of the cylinders. Results agreed well with those obtained by the rotating cylinder method of Wolarowitsch. At very small velocities, Bingham's equation for plastic flow does not hold for high concentration mineral suspensions. For Parts I–V see *Ceram. Abs.*, **15** [7] 222 (1936). F.P.P.

PATENTS

**Alkali silicate.** ANDERS E. A. CORNELIUS (Helios Kemisk-Tekniska Fabriker A.-B.). Swed. 80,000, April 4, 1934. *Chem. Abs.*, **29**, 6000 (1935).—Steam is blown into an electrically heated bath of alkali silicate formed by the reaction of alkali chloride and $SiO_2$. During the process the bath is kept covered by a layer of the unmelted charge of alkali chloride and $SiO_2$, with or without another substance, *e.g.*, lime, for the formation of double silicates.

**Method of manufacture of precipitated zinc oxide.** G. ANTONOFF. Brit. 459,238, Jan. 20, 1937 (June 5, 1935).

**Production of a calcium aluminate suitable for the manufacture of sodium aluminate by treatment with soda lye.** AKTIESELSKAPET NORSK ALUMINIUM CO. Brit. 457,676, Dec. 16, 1936 (Aug. 30, 1934).

## General

**Animal silicosis.** H. SIEGMUND. *Verhandl. Deut. Path. Ges.*, pp. 262–71 (1934); *Chem. Abs.*, **29**, 8169 (1935).

**Causation of pneumonoconioses.** PHILIP DRINKER. *Jour. Ind. Hyg. & Toxicol.*, **18** [8] 524–36 (1936).—The various pneumonoconioses and their causative agents are discussed. Silicosis and asbestosis are definite diseases; in anthraco-silicosis and various silicatoses, modifications of normal lung conditions are seen. Effects of carbon or carbonates, gypsum, and iron oxides are also discussed. Methods of estimating dust exposures of a workman include the taking of dust samples from the work place and interpreting the results during the man's total period of exposure. Errors made from estimating the composition of dust from samples which have settled upon rafters instead of using samples taken from the air are emphasized. Permissible dust concentrations need not exceed 50 million particles per cu. ft. for dust with very low quartz content or 5 million for pure quartz. In defense of the use of standards of dustiness, the experience in S. Africa where dust standards have been applied successfully for many years is cited. E.J.V.

**Charles N. Brady.** ANON. *Bull. Amer. Ceram. Soc.*, **16** [2] 73–74 (1937).

**Chemical considerations on some pneumoconioses (anthracosis, silicosis): I, Nature of the problem.** RENÉ FABRE. *Congr. Chim. Ind., 14th Congress, Paris*, 5 pp. (1934); *Chem. Abs.*, **29**, 5774 (1935).

**Clinical aspects, diagnosis, and treatment of pneumonoconiosis.** W. IRVING CLARK. *Jour. Ind. Hyg. & Toxicol.*, **18** [8] 537–49 (1936).—Pneumonoconiosis is a disease resulting from the inhalation of inorganic dust. The two pneumonoconioses which produce disability are silicosis and asbestosis. The pathology of silicosis is characterized by the presence of fibrotic nodules scattered through both lungs, and that of asbestosis is characterized by an interstitial fibrosis involving the lower half of both lungs. The symptoms of silicosis and asbestosis are similar, the most important being dyspnea. The most common complication is pulmonary tuberculosis which, in silicosis, is a frequent cause of death. The diagnosis of both silicosis and asbestosis is made largely by a correlation of history and symptoms with the X-ray examination. The treatment of pneumonoconiosis is preventive and symptomatic. The course of silicosis and of asbestosis is slow but eventually leads to incapacity due either to the disease itself or to a complication, frequently chronic pulmonary tuberculosis. The number of workers exposed to harmful mineral dusts in mining and in industry in the U.S. has been estimated as 500,000. E.J.V.

**Clinical hematological studies for the differential diagnosis of industrial silicosis.** C. SCHLOMKA AND F. A. NOLTE. *Klin. Wochschr.*, **14**, 987–92 (1935).—The authors have experimented with the pathological-anatomical actions of the changes of the silicotic lungs in connection with the heart and the complete bloodstream. With the assistance of electrocardiograms, they have been able to investigate the condition of the lungs of silicotic patients. At the policlinic of Bonn University, Röntgen observations of the last 190 silicosis patients were taken, and these were analyzed according to pure radiological points of view. Various tables showing the bloodcounts of several silicotic and tubercular patients were compiled. After certain peculiarities were established in the blood stream of the silicosis patients, it was found necessary to make further investigations of the connections between the studies of the blood and the clinical Röntgenological status. To obtain a most secure foundation, it was decided to separate those silicosis patients from the others who showed an important degree of tubercular complications. A characteristic blood status was shown in stone dust patients. This shows clearly excessive increase of white blood corpuscles with increased sinking at approximate normal counts of red corpuscles and distinct small counts of lymphocytes at relative transitional forms of lemkocytes in a streak preparation. The same symptoms, even if less impressive, are shown in a second group from the total of silicosis patients as positive cases with tuberculosis complications. W.F.F.

**Colored ceramic aggregate for decorative concrete.**

C. W. PLANJE. *Jour. Amer. Ceram. Soc.*, **20** [3] 90–96 (1937).

**Diagnosis of silicosis.** EMERY R. HAYHURST. *Amer. Labor Leg. Rev.*, **26**, 61–66 (1936); abstracted in *Jour. Ind. Hyg. & Toxicol.*, **18** [8] 131–32 (1936).—Factors necessary to diagnose chronic silicosis are: (1) exposure to silica dust in sufficient quantity for 5 to 20 years; (2) determination by intraperitoneal injection of the nodule-forming character of the dust; (3) nature of the work; (4) personal factors such as mouth breathing, previous respiratory diseases, etc.; (5) X-ray findings. Serial pictures should be taken over a period of time. The location of the nodules is characteristic, avoiding the periphery, symmetrical distribution, shape, and size. In this phase chronic silicosis is without disability. (6) Physical examination; no characteristic but some suggestive findings. (7) The patient's complaints: these are negligible in the first and second stages, but later cough, dyspnea, pains in chest, etc., may occur. E.J.V.

**Economizers and air preheaters.** V. WALKER. *Elec. Rev.*, **119** [3082] 853 (1936).—W. discusses the conditions which govern the design of economizers and air preheaters for use with boilers. J.L.G.

**Epidemiological aspects of silicosis and tuberculosis.** ALTON S. POPE AND DAVID ZACKS. *Amer. Rev. Tuberculosis*, **32**, 229–42 (1935); *Chem. Abs.*, **29**, 7524 (1935).—In representative groups of both granite and foundry workers in Massachusetts, the frequency of silicosis and of silicosis and tuberculosis was correlated with the duration of exposure to dusts containing free silica and to the concentration of such dusts in the occupational environment. Among granite workers silicosis was found in 15.2% and with tuberculosis in 7.6%. Tuberculosis is the cause of death in over one-third of all granite workers, a proportionate mortality 3 times that in foundry workers and 4 times that in all males of 20 years and over. Among the employees of 10 Mass. foundries, silicosis was found in 8.8% and with tuberculosis in 2.6%, a total frequency of one-half that in granite workers. The silicosis in foundrymen was not only less frequent but also less advanced in degree than in the granite workers. Pneumonia, causing one-fourth of all the deaths of foundrymen, is the greatest occupational hazard in the industry.

**Industrial health hazards and employer responsibility.** W. J. MCCONNELL. *Trans. Amer. Foundrymen's Assn.*, **7** [1] 161–65 (1936).—The importance of greater attention to the problem of overcoming industrial health hazards for foundry employees is recognized. Medical aspects are discussed, foundry hazards are outlined, and suggestions for a control program are given. D. E. CUMMINGS. *Ibid.*, pp. 166–79.—With the invention of the machine, dust became an industrial hazard. C. discusses the action of dust in the lungs and points out that all dusts are not dangerous. Silica dust is one of the dangerous dusts but only when present in certain concentrations of certain particle sizes. The silicosis problem is complicated by the fact that in many cases there is also decided evidence of the presence of tuberculosis. In foundries many men with normal lungs work for years and do not contract silicosis although there may be evidence of fibrosis. C. explains the action of dust particles inhaled on previous pulmonary injuries and states that workmen who are disabled by occupational fibrosis contracted in the foundry generally are those who exhibit evidence of concurrent pulmonary infection or injury. It is the executive's responsibility to inform himself on dust hazards, conduct surveys of his plant, and inaugurate a program of control. Prospective employees are grouped into three general groups; those which are fair risks and those which should not be employed are indicated. C. recommends that an educational program similar to that used in "Safety First" campaigns be inaugurated to combat the dust hazard. **Discussion.** AVEY *et al.* *Ibid.*, pp. 180–90.—The various ways of preventing illness are pointed out, and precautionary measures taken in the foundry are outlined. H.E.S.

**Industrial pulmonary disease due to inhalation of dust, with special reference to silicosis.** E. L. MIDDLETON. Milroy Lectures, 1936. *Lancet*, pp. 1–9 (July 4); pp. 59–64 (July 11, 1936); abstracted in *Jour. Ind. Hyg. & Toxicol.*, **18** [8] 129–30 (1936).—The first lecture is devoted to silicosis, as being the most important of the pneumonoconioses. Particular attention is directed to the occurrence of the disease according to occupation. During 1930 to 1934, at least 1521 deaths occurred in England and Wales; of these, 372 were caused in the sandstone industry, and 326 were ascribed to coal mining; the manufacture of pottery claimed 270, metal grinding 142, gold miners, returned from S. Africa, 104, and tin miners 91. The disease is always originated by the dust of fine particles of free silica; the way in which this risk is present in a number of industries is explained. Sandblasting and the manufacture of abrasive soaps receive special note, as in both the hazard is so intensive that the onset of the disease is unusually quick and its course rapid; thus only 3 or 4 years of employment may have preceded the onset, instead of 15 to 20 years as in most other occupations. The occurrence of cases in coal mining is unexpected, since coal itself is not a dangerous dust; apparently the disease is originated by dust arising from the rocks among which silica is found or from impurities in the coal. Out of 169 deaths on all coal fields in Great Britain, 147 came from S. Wales; this undue proportion has not yet been explained. The picture, both clinical and histological, becomes modified when silica is mixed with other forms of dust; when coal is associated in the dust, the condition is known as anthracosis; here the fibrous tissue entangles the coal dust and retains it to help in blocking up the lymphatics. In the second lecture the influence of the dust of silicates, *i.e.*, of chemically combined silica, is considered. Of these, asbestosis stands out as most toxic; the particles consist of fragments of fibers, some 3 microns long and $\frac{1}{2}$ micron in diameter. They originate pulmonary fibrosis which is more generalized and less nodular than that of silicosis; the condition develops quicker than silicosis, but the tendency to succumb to superimposed tuberculosis is not as pronounced. Other dusts considered are those of sillimanite, china clay, talc, mica, and sericite; none of them approach asbestos and silica in their dangerous qualities. The harmful nature of any dust may be tested by noting the reactions which follow when it has been either injected subcutaneously or administered by the tracheal route suspended in fluid; injection into the peritoneal cavity may also be employed. The theory adopted is that dusts exert their harmful influence by reacting chemically with

the tissues of the lungs, the life and structure of which are thereby modified. Each form of dust stimulates a special reaction of its own, while mixed dusts set up a mixed reaction. No evidence is put forward that dusts other than those of silica or silicates are harmful, or that any dust is capable of reducing the toxic influence of any other.

E.J.V.

**Investigations on quartz and sericite analysis of industrial dusts.** F. SARTORIUS AND K. W. JÖTTEN. *Arch. Hyg. & Bakteriol.*, **115**, 135–51 (1935); abstracted in *Jour. Ind. Hyg. & Toxicol.*, **18** [4] 54 (1936).—The separation of various mineral constituents of dusts by the use of liquids having suitable specific gravities is discussed. The standard methods of mineralogical and chemical analysis of dusts are mentioned, with a description of the X-ray examination. Some of the common minerals are shown. Mention is made of the mineralogy of sericite. E.J.V.

**Methods of dust control.** J. D. LEITCH. *Trans. Amer. Foundrymen's Assn.*, **7** [1] 209–21 (1936).—The point to begin elimination of the dust hazard is at the source. Methods used for controlling the dust hazards originating at different types of sources are described. L. discusses the general methods used in dust-suppression problems and the estimation of the hazard, contending that the efficiency of a dust-collection system is best determined by dust counts. Methods used for testing ventilating equipment and the selection of fans are presented. Dust collectors and respirators, such as helmets, filter-type respirators, and positive-pressure masks, are discussed. Maintenance of equipment is necessary to the successful operation of such equipment and to the efficiency of any installation. A discussion is included.

H.E.S.

**Molding of clay after heating at various temperatures.** R. MORETTI. *Corriere Ceram.*, **15**, 221–23 (1934); *Chem. Zentr.*, **1934**, ii, 3296; *Brit. Chem. Abs.-B*, **54** [27] 591 (1935).—Heating at 100 to 500° before molding increases the apparent porosity of the product fired at 900° and decreases the resistance to breaking of a specimen dried at 120°.

**Nomograph for ceramic calculations.** A. A. GUSINSKIĬ. *Ogneupory*, **3** [5] 374–76 (1935).—The nomograph facilitates the chemical analyses and the calculation of the amount of oxides in the fired product and of the raw material required for a given quantity of the latter.

P.B. & E.S.

**Personnel management.** J. E. WALTERS. *Factory Management & Maintenance*, **94** [12] S333–44 (1936).—The topics considered are (1) personnel management costs, (2) selection of employees, (3) personnel maintenance, (4) training and education, (5) medical and health service, (6) safety and accident prevention, and (7) personnel service work. Figures, tables, and photographs are included.

J.L.G.

**Significance of free crystalline silica in the etiology of silicosis and silicotuberculosis.** K. W. JÖTTEN AND H. POPPINGER. *Med. Welt.*, **10**, 545–50 (1936); abstracted in *Jour. Ind. Hyg. & Toxicol.*, **18** [8] 130–31 (1936).—The authors dusted rabbits over a period of four years, first 2, then 3, then 6 hr. daily, with porcelain dust having 30% free silica and 1 to 2% sericite. After this period the animals showed no typical silicosis although there could be seen sharp, pinpoint-sized, subpleural foci and a slight increase of fibrosis. During the dusting, tubercle bacilli were administered intravenously. These grew slowly, and with indurating processes, into a pulmonary tuberculosis while the controls showed no noteworthy disposition to contract tuberculosis. It is concluded that over a 3 to 4 year period of dusting with tubercle bacilli injected, it was possible to produce a tuberculosilicosis, although with the dust alone it was not possible to show silicosis, in spite of the presence of sericite. By dusting with pure quartz (without tuberculosis injection and without sericite) for 1 hr. daily for 2 years, typical silicotic nodules were produced.

E.J.V.

**Silicate analysis in industrial dusts.** F. SARTORIUS AND K. W. JÖTTEN. *Zentr. Gewerbehyg. & Unfallverhüt.*, **21**, 65–69 (1934).—Materials studied were from the Rhine Steel Works, the Thyssen, and the U. S. Steel Co. Tables show in detail the procedure and results, accompanied by ample comment and description of methods involved. If dusty occupations are to be graded on a danger scale over long or short periods, the sickness percentages and dust analyses must be carefully compared. These new research methods are concerned with the size of grains in dust raised and the accurate preparation of undissolved acid particles, thus serving the combined purposes of mechanical phase analysis and chemical analysis. Important insight into the structure of different kinds of dust has been gained, and this has been increased by using definite purity tests, *e.g.*, the tetralin method.

K.R.

**Silicosis: harmful dusts which cause it.** W. R. JONES. *Trans. Ceram. Soc.*, **34**, 303–43 (1935); see *Ceram. Abs.*, **14** [3] 84 (1935).

**Silicosis in the porcelain industry from the standpoint of the physician.** SCHILFFAHRT. *Ber. Deut. Keram. Ges.*, **17** [6] 322–30 (1936).—It is pointed out that a silicotic lung rarely occurs by itself, being usually associated with tuberculosis. A description of a silicotic lung is given. S. outlines the two theories of silicosis, mechanical and chemical, and discusses the chemical aspect of the problem.

E.J.V.

**Training your own instrument men.** ALFRED G. MOON. *Instruments*, **10** [1] 15–18 (1937).—M. reviews basic considerations, qualifications of candidates, training of instrument men, division of time between various types of repair jobs, supplementary educational work, progress reports, and rating guide to be used in semiannual check-up.

R.W.R.

BOOKS AND BULLETINS

**Determination and Control of Industrial Dust.** J. J. BLOOMFIELD AND J. M. DALLAVALLE. *U. S. Pub. Health Bull.*, No. 217, 167 pp. (April, 1935).—This brief but comprehensive work presents "the methods and instruments used in conducting dust studies in industry, the interpretation of results thus obtained, and their practical application to industrial problems, especially those phases relating to control of the dust hazard." Preliminary procedure involves the sanitary and occupational survey of a plant; final emphasis is placed on personal respiratory protection of workers. Between these occurs the dust technique,

achieved through appliances, dust study, and dust control. The paper is uniformly clear in presentation, and the authors have shown selective power and discrimination. This bulletin should appeal to engineers, plant owners and managers, and their employees. 39 tables, 77 illustrations, 73 references. K. REED

**Directory of Ceramic Industries of New York.** Published by Ceramic Assn. of New York, Alfred, N. Y. 72 pp. Price 25¢. Reviewed in *Ceram. Age*, **28** [1] 32 (1936).—This directory includes all branches of the ceramic industries in the State, from raw materials to finished products, the latter covering whiteware, glass, refractories, heavy clay products, and miscellaneous ceramic ware. Current information is given on plants, products produced, equipment facilities, and names of officials. A complete alphabetical index is included. F.G.H.

PATENTS

**Colored granule.** C. E. HILLERS (Blue Ridge Slate Corp.). U. S. 2,070,359, Feb. 9, 1937 (March 21, 1935).

**Method of producing double-wall vessels of ceramic material and with rarefaction of the air within the wall spaces.** H. J. MOCZALA. U. S. 2,070,672, Feb. 16, 1937 (Feb. 8, 1935). A method of producing double-wall vessels of ceramic material and with rarefaction of the air within the wall spaces comprises manufacturing the raw walls separately, placing one wall inside the other, connecting the air-pervious walls with each other at their edge portions, applying a raw glazing mass to the surface of the shard thus produced, and then heating to a sufficiently high temperature to drive part of the air within the wall spaces through the walls, followed by a sealing of the walls by the glazing material.